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AMERICAN WATER WORKS ASSOCIATION

In this issue

AWWA's new address, after April 1:

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(see p. 35 P&R)

Journal

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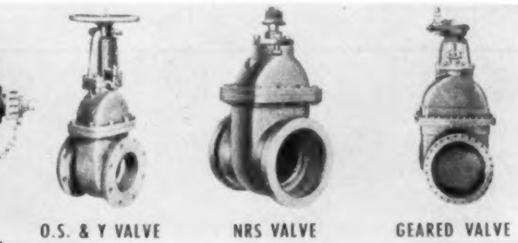

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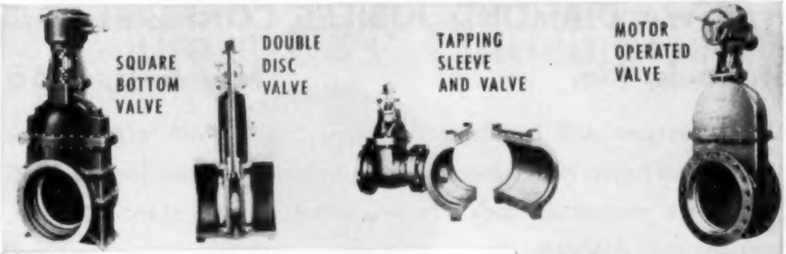

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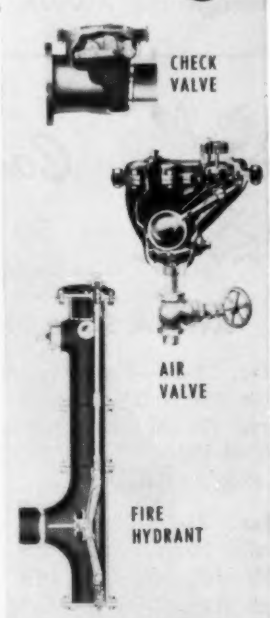

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St. Louis, Mo. **May 6-11, 1956**

All reservations will be cleared through the AWWA office. The nine official hotels have agreed to accept no reservations for the 1956 Conference except as they are requested on the standard form, through the AWWA.

Coming Meetings

AWWA SECTIONS

Mar. 18–21—Southeastern Section, at Bon Air Hotel, Augusta, Ga. Secretary, N. M. deJarnette, Georgia Dept. of Public Health, 245 State Office Bldg., Atlanta 3.

Mar. 21–23—Illinois Section, at LaSalle Hotel, Chicago. Secretary, D. W. Johnson, Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago 3.

Apr. 3–5—Pennsylvania Section, at Bellevue-Stratford Hotel, Philadelphia. Secretary, L. S. Morgan, State Dept. of Health, Greensburg.

Apr. 4–6—Kansas Section, at Jayhawk Hotel, Topeka. Secretary, H. W. Badley, Neptune Meter Co., 119 W. Cloud St., Salina.

Apr. 5–7—Arizona section, at Buena Vista Hotel, Safford. Secretary, Quentin M. Mees, Arizona Sewage & Water Works Assn., 721 N. Olsen Ave., Tucson.

Apr. 6–7—Montana Section, at Murray Hotel, Livingston. Secretary, A. W. Clarkson, State Board of Health, Helena.

Apr. 11–13—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, J. E. Olsson, Fulton & Cramer, 922 Trust Bldg., Lincoln.

Apr. 18–20—New York Section, at Hotel Utica, Utica. Secretary, Kimball Blanchard, Rensselaer Valve Co., 11 W. 42nd St., New York 36.

Apr. 23–25—Canadian Section, at Hotel London, London, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Apr. 26–28—Pacific Northwest Section, at Empress Hotel, Victoria, B.C. Secretary, F. D. Jones, Room 305, City Hall, Spokane, Wash.

(*Continued on page 10*)

Coming Meetings

(Continued from page 8)

Sep. 17–19—Kentucky-Tennessee Section, at Hotel Patten, Chattanooga, Tenn. Secretary, J. W. Finney Jr., Howard K. Bell Cons. Engrs., 553 S. Limestone St., Lexington, Ky.

Sep. 19–21—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, M. E. Druley, Dayton Power & Light Co., Wilmington.

Sep. 26–28—Wisconsin Section, at Stoddard Hotel, La Crosse. Secretary, L. A. Smith, Supt., Water & Sewerage, City Hall, Madison 3.

OTHER ORGANIZATIONS

Mar. 19–20—Steel Founders Society of America, Drake Hotel, Chicago, Ill.

Mar. 26–30—Annual Public Utilities Safety Course, National Safety Council, Chicago, Ill. Glenn F. Griffin, Director of Industrial Training, National Safety Council, 425 N. Michigan Ave., Chicago 11.

Apr. 3–5—Short Course on Corrosion, at University of Oklahoma Extension Study Center, Norman, Okla.

Apr. 5–6—Southern Municipal and Industrial Waste Conference, Chapel Hill, N.C. For information write D. A. Okun, Dept. of Sanitary Engineering, University of North Carolina, Chapel Hill, N.C.

Apr. 17–18—Annual Municipal and Sanitary Engineering Conference, University of Florida, Gainesville, Fla.

May 4—Annual Conference for Engineers, College of Engineering, Ohio State University, at Ohio Union, Columbus.

May 12–15—German Engineers Assn. Centenary Celebration. Verein Deutscher Ingenieure, Prinz-Georg-Strasse 77/79, Dusseldorf, Germany.

Jun. 4–8—National Fire Protection Assn. Annual Meeting, Hotel Statler, Boston, Mass.

Jun. 4–8—American Society of Civil Engineers, Knoxville, Tenn.

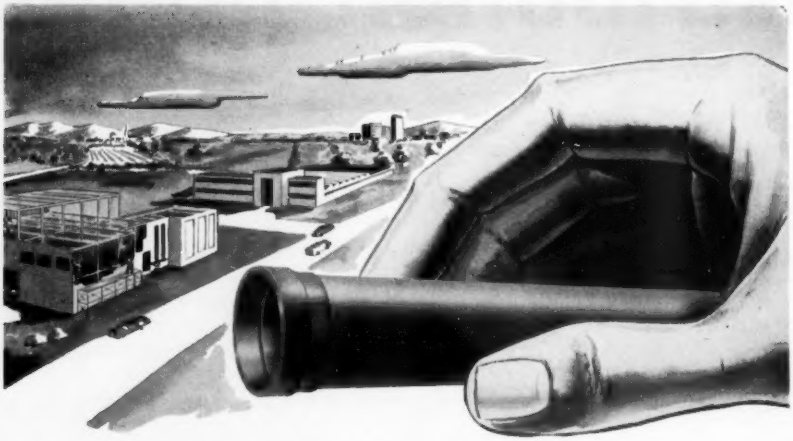
Jun. 17–23—World Power Conference, Vienna, Austria. US National Committee, World Power Conference, 29 W. 39th St., New York 18, N.Y.

Jul. 30–Aug. 3—Gordon Research Conference on Ion Exchange, American Assn. for Advancement of Science, at Kimball Union Academy, Meriden, N.H. W. George Parks, Director, Dept. of Chemistry, University of Rhode Island, Kingston, R.I.

Oct. 8-11—Federation of Sewage & Industrial Wastes Assns., Statler Hotel, Los Angeles, Calif.

Oct. 15–19—American Society of Civil Engineers, Pittsburgh, Pa.

Nov. 12–16—American Public Health Assn., Atlantic City, N.J.



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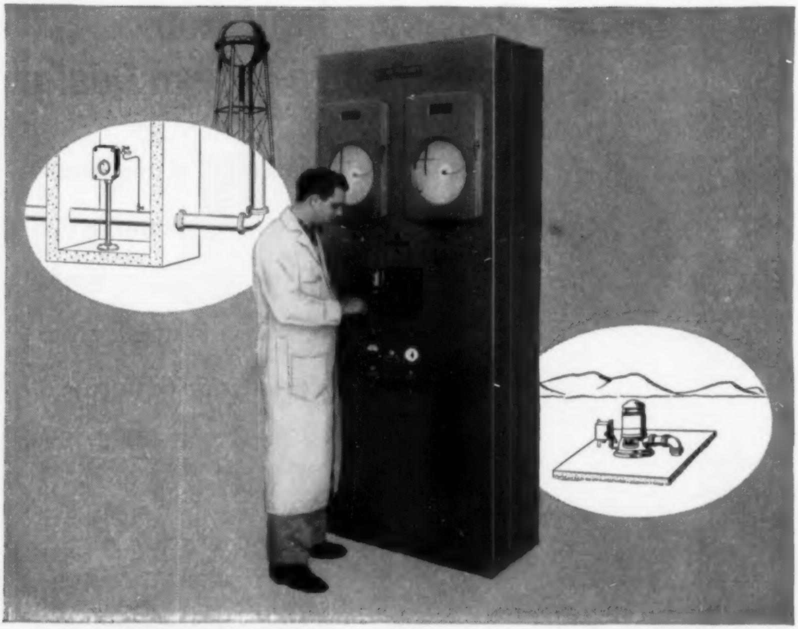

Journal

AMERICAN WATER WORKS ASSOCIATION

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Effects of Water Quality on Various Metals

Lee Streicher

A paper presented on Jun. 13, 1955, at the Annual Conference, Chicago, Ill., by Lee Streicher, Chief Chem., Metropolitan Water Dist. of Southern California, La Verne, Calif.

CORROSION in the field of municipal water supply is undoubtedly one of the major contributors to the estimated annual expense of several billion dollars caused by corrosion in the United States alone. Besides the monetary loss, however, corrosion promotes additional undesirable effects in the form of reduced pressure, impaired water quality, or annoying leaks, all of which lead to consumer complaints. These effects may not always become immediately apparent in the course of normal operation of a distribution system, but they often come to light very quickly when the water quality in the system is markedly changed. It is generally recognized that a pipeline conveying a uniform quality of water over a period of time will have developed deposits which are completely compatible with the existing environment. These deposits, whether biological, mineral, or a combination of both, usually remain relatively undisturbed as long as the water quality remains unchanged. If there is a significant change in water quality, however, disturbance of these deposits is almost certain to follow. This is particularly true where the change includes the introduction of chlorinated water into a distribution system formerly carrying an unchlorinated supply.

Distribution System Problems

When Colorado River water was first delivered to the member cities of the Metropolitan Water District of Southern California in 1941, new problems were brought to old distribution systems. It was probably fortunate that, at that time, the district had only thirteen member cities, rather than the 66 incorporated cities and extensive unincorporated areas that constitute its membership today (*1*). Even with the few distribution systems involved, however, the problems were extremely disturbing. Treated Colorado River water, as delivered to the member cities, differed in a number of respects from the various local supplies. It was softer than the well waters used in some cities, carried a chlorine residual, was saturated with dissolved oxygen, and had a higher dissolved-solids content. In some distribution systems

the old calcium carbonate and rust deposits were loosened, causing "red water" and, possibly, leaks due to exposure of previously covered pipe perforations. In other cities the destruction of long undisturbed biological growths gave rise to taste and odor problems. These unstable conditions usually persisted until new deposits, compatible with the new environment, were developed in the pipelines. Experience in a number of cities indicated that metaphosphate, applied during the period of transition from the old deposits to the new, helped appreciably to reduce the number of consumer complaints. In the very few instances where, in an effort to destroy existing growths, a chlorination program had been instituted before the introduction of Colorado River water, the immediate effects of the water quality change were relatively minor.

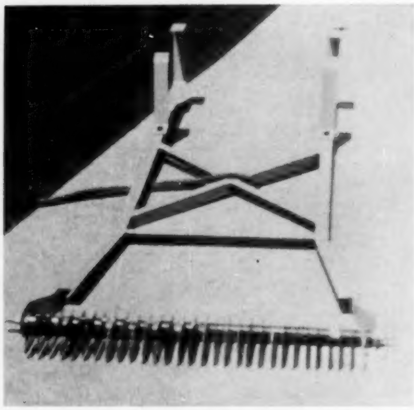


Fig. 1. Typical Assembly of Test Coupons

For each assembly, thirteen different metal strips and eight coupled strips were attached to a plastic pipe and mounted on a frame. The assemblies were submerged for 8 months.

Nature of Problems

After the period of transition, new problems arose. These, however, were not caused as much by chlorine content of the water as by its other characteristics. Complaints of water meters being plugged with a soft, white deposit were among the first to be reported in significant numbers. Laboratory analyses showed these deposits to be mainly basic zinc carbonate, sometimes enmeshed in a matrix of bacterial slime. An examination of the meter parts revealed that the sources of the zinc were the zinc stars and the yellow-brass sand rings. Removal of the zinc stars and substitution of copper or hard-rubber sand rings for the yellow brass materially reduced difficulties of this nature.

Trouble was encountered, also, with plugging of the gear trains in open-gear train meters. Again, dezincification was the prime cause. Replacement of the old meter heads with new closed-gear train assemblies proved to be a fully satisfactory solution to this problem.

A canvass of plumbers in several of the district member cities revealed that corrosion troubles were most severe where the water was further softened in household or industrial zeolite units, and at hot water-heater connections. In one city it was reported that 70–80 per cent of the plumbing repairs on hot-water service lines were required where zeolite softeners were used. This is not particularly surprising when it is realized that a high-conductivity water, saturated with dissolved oxygen, was made even more aggressive by removal of all of its calcium carbonate reserve. Where complete softening was especially desirable or essential, therefore, the use of all copper or red-brass piping assemblies was recommended.

Galvanic corrosion due to coupling of dissimilar metals was by far the most widespread and persistent type of corrosion encountered. The recommendation that such couples be eliminated by substitution of similar metals wherever possible, or by introduction of insulating couplings to break the electrical connection where the desired substitution was not possible, has been frequently and emphatically repeated over the years by the district staff. Acceptance of these recommendations has resulted in a substantial reduction in corrosion complaints of this nature.

which entails the cleaning of all meter parts by buffing, after which they are coated with a special grease.* The chambers are heated and dipped in "C" grease at 140°–160°F, drained, and the excess grease wiped from the interior. The housings are heated and "A" grease is brushed on the interior.

Subsequently, other member cities adopted this servicing procedure with equally satisfactory results to date. Some meter shops are still using an inhibited acid solution followed by a fresh water rinse, and they report good results from this practice. Others

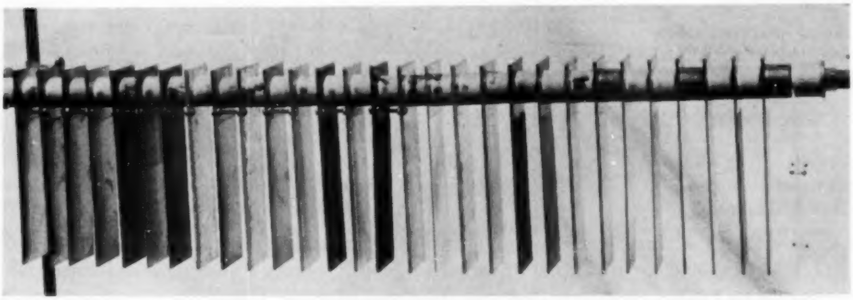


Fig. 2. Detail of Test Coupon Assembly

Short sections of larger-diameter plastic pipe were used as spacers between the specimens.

Meter Shop Practices

Meter-reconditioning procedures had an important relationship to the period of satisfactory meter service in the distribution system. Even before deliveries of Colorado River water were started, it was found in one city (Newport Beach) that cleaning with inhibited acid, even when followed by a caustic dip and a final rinse in fresh water, encouraged the relatively rapid formation of blue-green blisters on the bronze parts of the meters after they were again in service. Experimentation led to a servicing procedure which proved exceptionally satisfactory, and

simply buff the meter parts, leaving a thin film of oxide, and return the meter to service with no further treatment. On the basis of reports from the service shops it appears that the buffing and greasing procedure, although more time consuming than the others mentioned, probably leads to the longest periods of satisfactory meter service. In view of the rapid formation of blisters in some new meters, adoption of the practice of greasing the chambers in these prior to installation would undoubtedly prove to be beneficial.

* No-Ox-Id Grease, a product of Dearborn Chemical Co., Chicago, Ill., was used.

TABLE 1

Analyses of Waters Used in Corrosion Tests *

Item	Portion of Total Sample—*ppm*				
	Metropolitan Water Dist. (Colorado R. Water)		Los Angeles Aqueduct† (Owens R. Water)	Long Beach (Well Water)	
	Untreated	Treated		Untreated	Treated
Silica (SiO_2)	9.9	9.9	21	16.5	16.1
Calcium (Ca)	83	31	26	22	26
Magnesium (Mg)	29.5	11.5	6	2	2
Sodium (Na)	97	190	40	56	60
Potassium (K)	4	4	5	2	2
Carbonate (CO_3)	1	2	0	1	4
Bicarbonate (HCO_3)	149	142	156	193	186
Sulfate (SO_4)	292	292	25	11	11
Chloride (Cl)	81	85	19	16	28
Total dissolved solids	673	698	221	223	242
Hardness (as $CaCO_3$)—					
Total	329	125	91	64	73
Carbonate	124	120	91	64	73
Noncarbonate	205	5	0	0	0
pH	8.4	8.5	8.45	8.3	8.5
Dissolved oxygen	10.0	9.9	7.0–10.0	0‡	3.2
Residual chlorine	0	0.9	0.25	0	1.5
Color	4	3	12	38	6
Elec. Conductivity (*micromhos* $\times 10^6$)	1,050	1,120	350	323	360
Temperature (°*F*)	60	60	53		74

* Data represent averages for September 1954 through April 1955.
† Treatment of this supply consisted only of chlorination and copper sulfate addition.
‡ 0.3 ppm H_2S present.

In the district laboratory, a test of limited duration, wherein a number of test coupons were coated with silicone grease * and placed in a container into which district-treated water was flowing continuously, appears to be encouraging. Perhaps this or similar coating materials may be suitable for application to meter parts for extension of their useful service life.

Improvement of the alloys used in meter part fabrication is proving to be another valuable way of extending the duration of satisfactory meter service. Nickel-mix chambers in some of the newer meters, for example, have been reported to be entirely trouble-free after 2 years of operation. It is indicated that careful analysis of field experience supplemented by metallurgical investigations by meter manufacturers can lead to worthwhile improvements in meter design and operating life.

Special Corrosion Studies

As reports of corrosion in the distribution system may often reflect the personal opinions of the observers and are usually influenced by the relative experience prior to use of district wa-

* Silicone Grease DC-6, a product of Dow Corning Corp., Midland, Mich., was used.

TABLE 2

Weight Loss of Uncoupled Coupons in Various Waters

Item	Weight Loss in Coupon—*mg/sq dm/day*					
	Metropolitan Water Dist. (Colorado R. Water)		Los Angeles Aqueduct (Owens R. Water)		Long Beach (Well Water)	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Aluminum	2.46	1.37	6.18	9.59	0.47	0.87
Yellow Brass	10.21	9.02	4.18	10.33	0.14	5.31
Red Brass	2.98	3.72	2.28	7.21	1.61	3.22
Phosphor bronze	2.04	4.14	2.51	3.18	2.26	2.56
Copper	4.07	3.99	2.43	6.95	1.40	4.34
Galvanized iron	10.72	10.67	12.14	12.35	0.26	6.46
Black iron	11.92	38.18	16.61	35.23	6.59	25.11
Lead	1.56	1.72		2.95	0.96	3.41
Monel	0.02	0.04	0.01	0.12	0.63	0.02
Stainless steel—Type 410	15.72	49.33	0.04	0.30	0	0.10
Stainless steel—Type 316	0	0	0.01	0	0.01	0.01
Tin	2.70	0.93	0.25	0.54	0.24	3.86
Zinc	17.94	12.44	18.99	15.96	0.19	8.76
Duration of test (*days*)	234	234	236	236	236	236
Water velocity (*fps*)	1.6	1.6	2.7	2.3	0.7	0.5

ter, a corrosion test was designed to determine more quantitatively the effect of water quality on various metals. In Table 1 are shown analyses of the waters used for this test. The first column of figures gives the data for untreated Colorado River water as delivered to the district's treatment plant. This is a hard water relatively high in dissolved solids and saturated with dissolved oxygen. The second column shows the change in quality resulting from the cation-exchange softening, filtration, and chlorination processes used at the treatment plant.

Los Angeles aqueduct water is moderately soft and fairly low in dissolved solids. Treatment of this supply consists only of chlorination and copper sulfate addition for algae control. Therefore, the only difference between the treated and untreated waters is in the chlorine (and possibly copper) residual, as indicated in the third column of Table 1. Columns 4 and 5 give the analyses of untreated and treated Long Beach well water. As apparent from the analysis, the untreated well water is a naturally soft, colored water, and has a distinct odor of hydrogen sulfide. This water also has a low dissolved-solids content. The treatment process consists of color and odor removal by chlorination beyond the breakpoint, accompanied by long detention and followed by filtration.

Test Assemblies

Thirteen different metal test strips and eight pairs, each consisting of two unlike metal strips coupled together by means of a brass screw and nuts, were assembled on a plastic pipe slipped over a metal rod and mounted on a frame similar to the one shown in Fig. 1. Details of the mounting procedure and

TABLE 3

Weight Loss of Coupled Coupons in Various Waters

Item	Weight Loss in Coupon—*mg/sq dm/day*				
	Metropolitan Water Dist. (Colorado R. Water)		Los Angeles Aqueduct (Owens R. Water)	Long Beach (Well Water)	
	Untreated	Treated	Treated*	Untreated	Treated
Galvanized iron	10.13	11.31	12.00	7.70	10.28
Black iron	0.24	12.68	40.06	1.76	11.49
Galvanized iron	15.83	92.11	13.71	1.64	9.54
Yellow brass	0.07	0.24	7.31	0.15	4.58
Galvanized iron	16.40	13.09	19.89	7.30	10.22
Copper	0.19	0.10	3.19	4.31	3.62
Black iron	28.27	101.03	58.76	5.10	49.84
Copper	0.10	0.21	0.22	3.48	0.57
Yellow brass	20.96	9.90	11.81	0.70	6.08
Red brass	2.05	4.51	6.83	1.47	3.03
Yellow brass	19.77	9.89	11.75	0.37	6.21
Phosphor bronze	1.23	2.80	2.65	3.31	2.19
Aluminum	6.23	31.27	18.49	0.54	21.80
Red brass	0.04	0.16	0.09	1.29	0.36
Aluminum	4.09	1.37	10.67	0.52	3.30
Black iron	4.41	34.21	37.14	4.05	20.20

* No test coupons were installed in untreated water.

of the short sections of larger-diameter plastic pipe used as spacers between the individual specimens are shown in Fig. 2. Each test strip was approximately 8 in. long and 2 in. wide. Two inches at the mounting end of each strip (and of each pair after coupling) was dipped in strippable plastic paint, leaving a relatively uniform 6-in. length of each coupon exposed to the water. The bottom ¼ in. of each galvanized strip was also plastic-coated to avoid exposure of the cut end. Before the ends were coated, all of the coupons were carefully cleaned and weighed, and, after dipping, the uncoated areas to be exposed to the water were accurately measured.

One assembly of this type was installed in each of the waters described in Table 1, the only exception being that no coupled pairs were included in the assembly suspended in the untreated Los Angeles aqueduct water. After almost 8 months of submergence in the various waters, the assemblies were removed, photographed, and dismantled. All of the test strips were then examined singly and photographed, after which they were thoroughly cleaned of corrosion products and reweighed. The weight losses of

the uncoupled test coupons are shown in Table 2, and the losses for the coupled strips in Table 3. In Table 4 are shown the maximum depths of pits which developed in a number of the coupons.

Effect of Velocity

Before the weight loss data are evaluated and compared, it is necessary to point out that two factors, over which no control could be maintained, probably had very significant influence on the weight loss of some of the test coupons. These factors were water velocity and temperature. As shown at the bottom of Table 2, the velocities of flow differed only slightly, in each instance, between the untreated and treated waters from the same source, but they varied rather widely between the waters from different sources. Thus, a direct comparison may be permissible in each case between the weight losses of the untreated and the treated waters from the same source, but not necessarily between the test coupons in waters from different sources.

Tests to determine the effect of velocity of treated Colorado River water on the corrosion rates of a few different metals were completed in time for inclusion in this report. The data from these tests are shown in Fig. 3. Most unusual are the curves for black iron, showing an increase in corrosion rate with increases in water velocity up to about 4–6 fps, depending upon the water temperature, after which the corrosion rate decreased with further increases in velocity. Uhlig (*2*) and Speller (*3*) both point out that other investigators have reported similar observations. In discussing these reports, Uhlig offers the following explanation: "For these tests it is probable that high velocity brought sufficient oxygen to the iron surface to cause passivity in the same manner as high concentration of dissolved oxygen in water passivates iron." Strangely enough, when

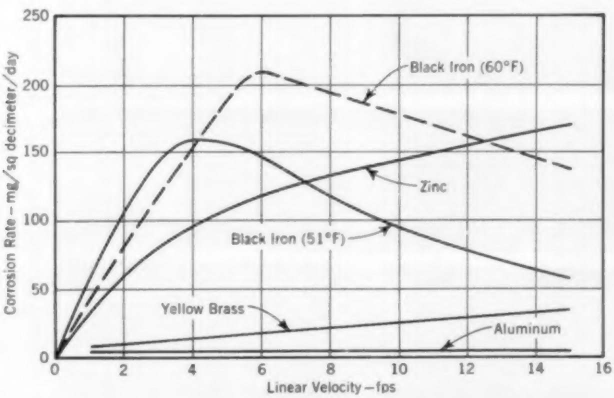


Fig. 3. Effects of Water Velocity on Corrosion Rate

The samples were submerged in treated Colorado River water. The period of exposure for the yellow brass was 5 weeks. All other samples were exposed for 2 weeks.

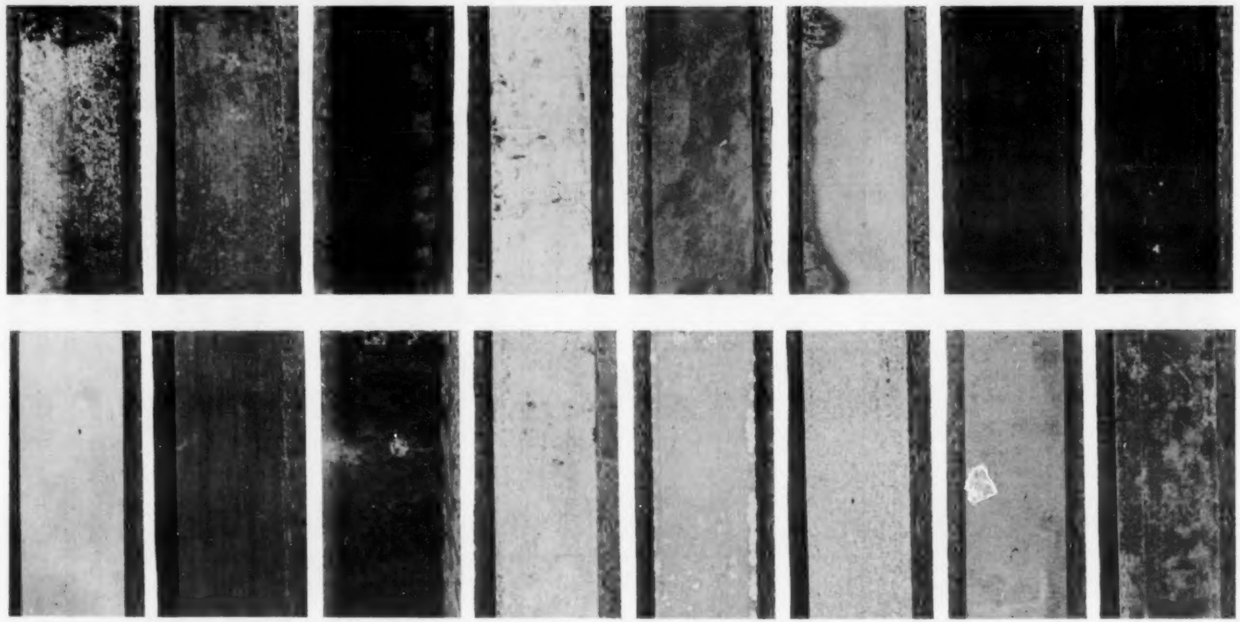


Fig. 4. Test Coupons From Long Beach Well Water

The top row of coupons is from untreated water, the bottom row from treated water. Coupons, from left to right in both rows, are: Monel, phosphor bronze, black iron, galvanized iron, aluminum, zinc, copper, and yellow brass. All coupons shown were used singly.

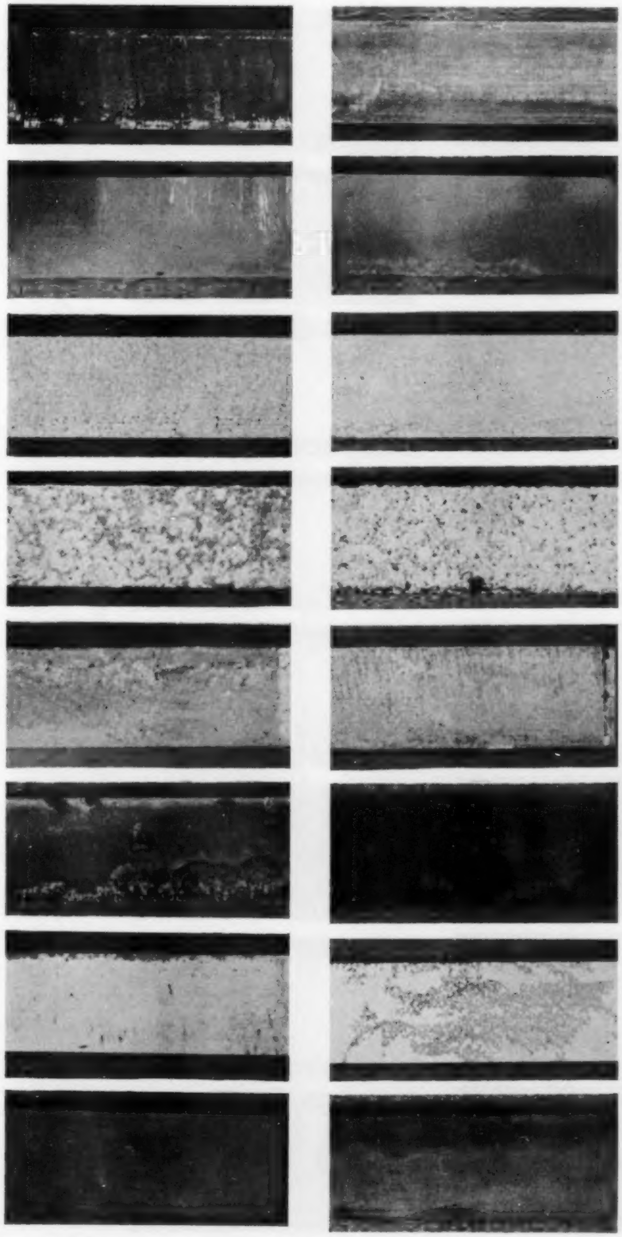


Fig. 5. Test Coupons From Los Angeles Aqueduct Water

The top row of coupons is from untreated water, the bottom row from treated water. Coupons, from left to right in both rows, are: lead, tin, black iron, galvanized iron, aluminum, zinc, copper, and yellow brass. All of the coupons shown were used singly.

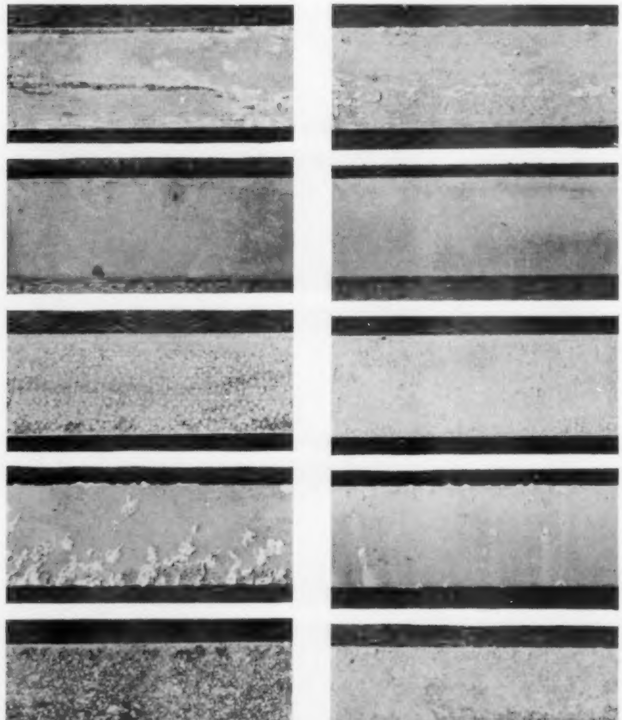


Fig. 6. Test Coupons From Colorado River Water

The top row of coupons is from untreated water, the bottom row from treated water. Coupons, from left to right in both rows, are: type 410 stainless steel, type 316 stainless steel, black iron, galvanized iron, aluminum, zinc, copper, and yellow brass. All coupons shown were used singly.

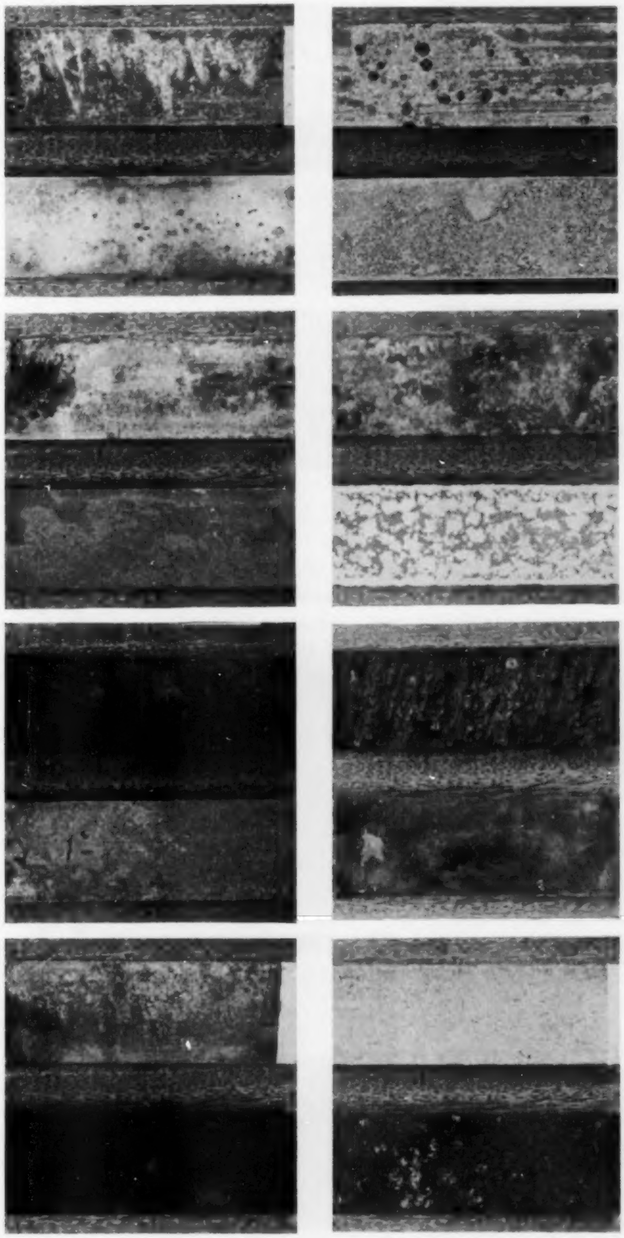


Fig. 7. Coupled Pairs of Test Coupons From Long Beach Well Water

The top row of coupons is from untreated water, the bottom row from treated water. Pairs of coupons, from left to right in both rows, are: black iron, galvanized iron; copper, black iron; aluminum, red brass; and yellow brass, galvanized iron.

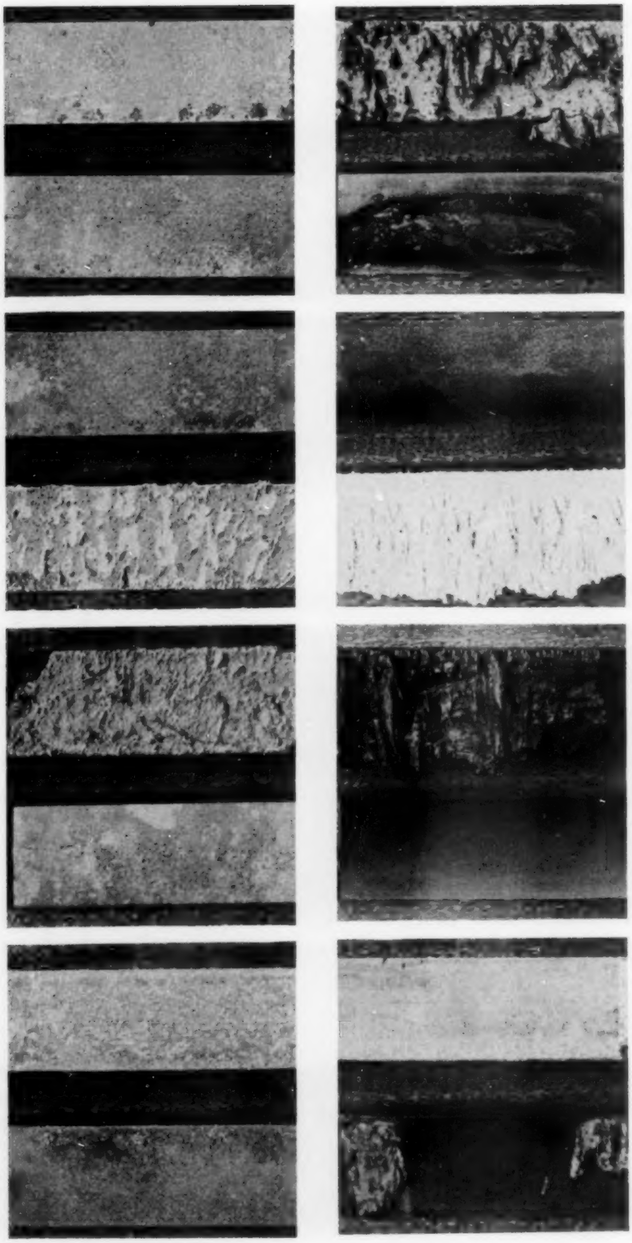


Fig. 8. Coupled Pairs of Test Coupons From Colorado River Water

The top row of coupons is from untreated water, the bottom row from treated water. Pairs of coupons, from left to right in both rows, are: black iron, galvanized iron; copper, black iron; aluminum, red brass; and yellow brass, galvanized iron.

this test was repeated with the black-iron strips in untreated Colorado River water, the corrosion rate increased continuously with increasing water velocity. Again the answer may have been indicated by Uhlig who, in commenting on the inability of certain investigators to duplicate the phenomenon of corrosion rate reversal described above, stated that in certain experiments "a thin layer of rust may have prevented concentration of oxygen on the metal surface." In the district experiments, the harder, untreated water may have deposited a thin film of calcium carbonate, which helped to bind the corrosion product more firmly to the surface of the black-iron coupons, and this coating may have performed the function of the layer of rust referred to by Uhlig. Although this curiously opposite behavior in the two waters is quite interesting, it has no direct bearing on the results of the field tests described above, because the velocities in the six channels were all within the range in which corrosion rates increased continuously with increasing linear velocity. Even though the degree of increase in corrosion rate with increasing velocity may not be as great over a period of 8 months as it was in the 2-week velocity tests, some increase can still be expected. Water velocities should therefore be taken into consideration in any comparison of the corrosion rates of iron in the waters from the three different sources.

The same caution will apply to the data relating to the zinc coupons, because the rate of corrosion of zinc also showed a marked increase with increasing water velocity in the 2-week velocity tests. With respect to the aluminum and yellow-brass coupons, the corrosion rates did not increase significantly with increasing flow rates. Therefore, a more direct comparison between the corrosion rates for these metals may be allowable.

Uncoupled Coupons

It is interesting to note that the treated waters were more aggressive than the corresponding untreated waters in their attack on most of the metals. One characteristic common to all three treated waters was the chlorine residual which they carried. This was the only important difference between untreated and treated Los Angeles aqueduct water, except for a trace of copper which remained in the latter as a result of the copper sulfate treatment. Removal of the color-producing organic matter, which apparently formed a protective film in pipelines carrying, untreated Long Beach well water, was probably responsible to a major extent for the increased aggressiveness of this water after treatment. The chlorine residual and the dissolved oxygen in the treated well water may also have contributed to its corrosiveness. Substitution of sodium for much of the calcium and magnesium in untreated Colorado River water reduced its tendency to deposit a protective calcium carbonate film and, at the same time, increased its conductivity. These changes, coupled with the introduction of chlorine, probably account for the increased corrosiveness of this treated water.

From the data given in Table 2 it is apparent that only in its effect on Monel was the untreated Long Beach well water more corrosive than any of the other five waters. To most of the other metals it was least corrosive. (It should be remembered, however, that the water velocities were lowest in the Long Beach water channels.) Uhlig indicates that "the nickel-copper alloys

are corroded at a moderate rate by moist hydrogen sulfide, and corrosion is accompanied by the formation of a sulfide tarnish." The hydrogen sulfide in the untreated Long Beach well water was probably largely responsible for the relatively high rate of corrosion of the Monel. The validity of this conclusion is further confirmed by the fact did in the two river waters, however. As indicated above, this can probably be attributed to the removal of the organic film-forming agents in the untreated water and to the introduction of oxygen and free chlorine. Figure 4 illustrates the effects of untreated and treated Long Beach waters on some of the coupons tested.

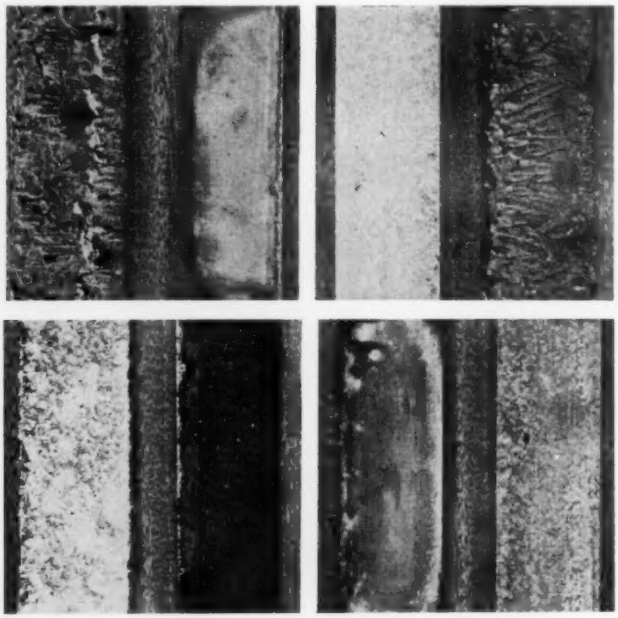


Fig. 9. Coupled Pairs of Test Coupons From Treated Los Angeles Aqueduct Water

Pairs of coupons, from left to right, are, top: black iron, galvanized iron; copper, black iron; and bottom: aluminum, red brass; and yellow brass, galvanized iron.

that in the treated water, from which the hydrogen sulfide had been removed, corrosion of the Monel was insignificant.

The treated Long Beach water was usually less corrosive than the other treated waters. Treatment appeared to cause a much greater increase in aggressiveness of this well water than it

Untreated Los Angeles aqueduct water was particularly aggressive to aluminum, black iron, galvanized iron, and zinc. Similarly, the treated water was most corrosive to aluminum, the brasses, copper, galvanized iron, lead, and zinc, as shown in Fig. 5. The higher velocities in the Los Angeles aqueduct channels were undoubtedly

TABLE 4

Effects of Various Waters on Pitting in Coupons

Item	Maximum Penetration of Pits—*in. per yr*					
	Metropolitan Water Dist. (Colorado R. Water)		Los Angeles Aqueduct (Owens R. Water)		Long Beach (Well Water)	
	Untreated	Treated	Untreated*	Treated	Untreated	Treated
Uncoupled Coupons						
Aluminum	0.0315	0.024	0.027	0.030	‡	0.0105
Galvanized iron	0.0195	0.0165	0.021	0.015	‡	0.0075
Black iron	0.012	0.0255	0.039	0.0135	0.0075	0.018
Stainless steel—Type 410	0.0315	0.1185†	‡	‡	‡	0.009
Zinc	0.027	0.018	0.0195	0.0105	0.006	0.0105
Coupled Coupons						
Galvanized iron	0.0105	0.0105		0.015	0.0075	0.015
Black iron	0.003	0.021		0.018	0.0075	0.0165
Galvanized iron	0.0105	0.066		0.018	‡	0.015
Yellow brass	‡	‡		‡	‡	‡
Galvanized iron	0.015	0.0135		0.021	‡	0.018
Copper	‡	‡		‡	‡	‡
Aluminum	0.0615	0.1005		0.0615	‡	0.060
Red brass	‡	‡		‡	‡	‡
Aluminum	0.033	0.012		0.033	‡	0.030
Black iron	0.009	0.018		0.0135	0.009	0.0105
Black iron	0.018	0.0345		0.0195	0.0045	0.0225
Copper	‡	‡		‡	‡	‡

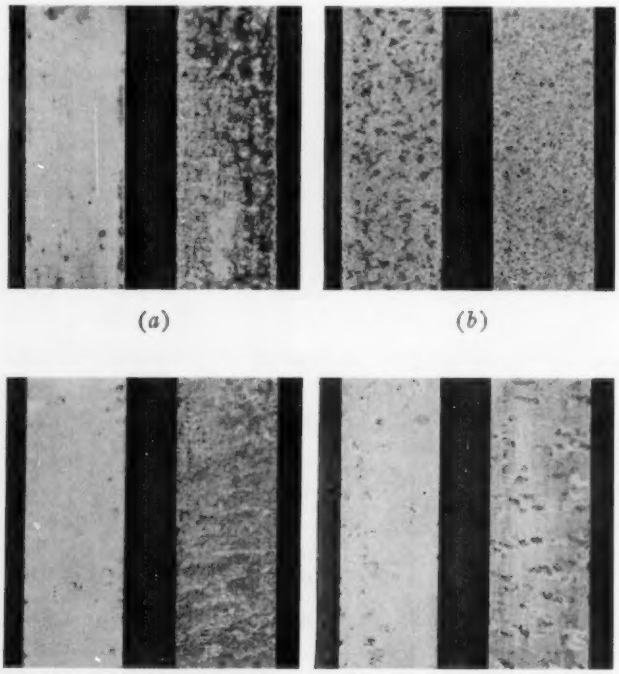
* No coupled test coupons were installed.
† Hole through test coupon.
‡ No evidence of measurable pits.

responsible for the higher corrosion rates of the black iron, galvanized iron, zinc, and possibly lead. The relatively high rate of corrosion of aluminum in the treated water may be due to the presence of a trace of copper in the water which might have produced minute galvanic cells, but this would not explain why the attack on aluminum was also pronounced in the raw water. The high rate of corrosion of copper and the brasses in the treated water is also somewhat puzzling, but may have been caused, in part at least, by the high dissolved-oxygen content of the water.

Whereas Type 410 stainless steel was attacked only very slightly, if at all, by the other four waters, in both untreated and treated Colorado River water it was very severely corroded (*see* Fig. 6). In every case, corrosion of this alloy was evidenced by tuberculation and pitting. When the tubercles on the coupon submerged in the treated water were removed, the metal was

found to have been penetrated in several places. In discussing the theory of pitting in stainless steels and other passive metals, Uhlig states:

Pits begin by breakdown of passivity at favored nuclei on the metal surface. The cell accounts for considerable flow of current with attendant rapid corrosion at the small anode. The corrosion-resistant passive metal surrounding the anode and the activating property of the corrosion products within the pit account for the tendency of corrosion to penetrate the



(*a*) (*b*)

(*c*) (*d*)

Fig. 10. Corrosion of Aluminum in Different Waters

The coupon on the left of each pair was uncoupled, the coupon on the right was coupled to red brass. Coupons shown were from: (a) *treated Long Beach well water;* (b) *treated Los Angeles aqueduct water;* (c) *treated Colorado River water; and* (d) *untreated Colorado River water.*

breakdown is followed by formation of an electrolytic cell, the anode of which is a minute area of active metal and the cathode of which is a considerable area of passive metal. The large potential difference characteristic of this passive-active metal rather than spread along the surface.

The high conductivity of Colorado River water is conducive to current flow and stimulates the type of corro-

sion described. Type 316 stainless steel, a nickel-chromium-molybdenum steel, was completely undamaged. The high conductivity and the condition of saturation with dissolved oxygen are probably the two factors largely responsible for the rapid corrosion of black iron, galvanized iron, and yellow brass in Colorado River water.

Coupled Coupons

The eight pairs of coupled strips were included in the test assembly to simulate the galvanic cells which occur when dissimilar metals are directly connected in a pipe assembly. The corrosion rates for these couples are given in Table 3, and photographs of the corroded coupons before cleaning are shown in Figs. 7–9.

With the coupled coupons, as with the uncoupled ones, untreated Long Beach water was the least corrosive of the waters used. Its behavior was rather peculiar, however, in the respect that in several instances both members of a couple were corroded more than the corresponding uncoupled specimens in the same water. One striking example of this abnormal behavior is represented by the couple constructed of galvanized iron and copper. As would be expected, in all other waters the galvanized iron was anodic to the copper and the corrosion rate of the former increased while that of the copper decreased in comparison with the corresponding uncoupled coupons. In Long Beach untreated water, however, not only did the weight loss of the galvanized iron increase very markedly, but, at the same time, the copper was etched (*see* Fig. 11) and its corrosion rate tripled. Probably in this case, as well as in the others where the corrosion rate of both members of the couple increased, the combination of hydrogen sulfide and galvanic-current flow was responsible. Treated Long Beach water was more "normal" with respect to its effect on galvanic couples.

In treated Los Angeles aqueduct water the differences in corrosion rates between the coupled strips and the corresponding uncoupled ones were generally less pronounced than in the other waters. When this was noted on the first two or three couples checked it was thought that, possibly, a poor bond had been made between the members of the couples. In view of the number of couples which showed this behavior, however, it may probably be inferred that coupling does not significantly change the corrosion rates of these metal combinations in this type of water. The exceptions to this were the couples which included either copper or red brass as one member of the pair.

In view of the relatively high conductivity of both treated and untreated Colorado River water, it is not surprising that marked changes in corrosion rates occurred when certain metals were coupled. This confirms the experience in the distribution system of the district member cities—that galvanic corrosion is the most persistent and troublesome type encountered. In almost every case the rate of corrosion of the anodic metal increased while that of the more noble metal in the couple decreased. The effect was most pronounced where copper or a copper-bearing alloy was coupled to a metal containing no copper. Typical of this last group was the combination of aluminum and red brass which, unfortunately, is used in some metering devices. In this couple, pitting of the aluminum becomes very pronounced, even with the other waters of lower conductivity, as shown in Fig. 10.

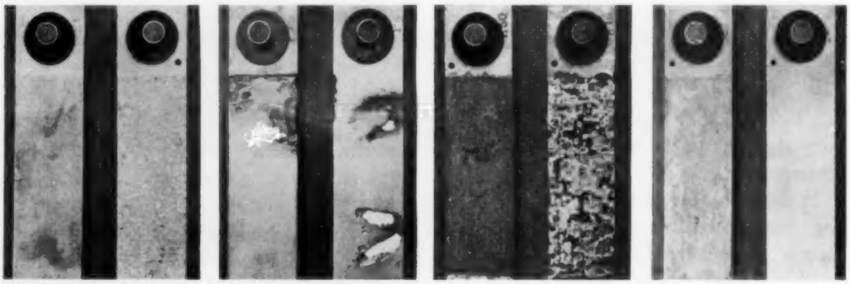
Pipe Nipple Tests

In April 1954 a corrosion study was initiated to determine the variation in corrosion rates of black-iron and galvanized-iron pipe nipples exposed to untreated and to treated Colorado River water for various lengths of time. Eight rows of nipples were set up with the flow conditions as follows:

1. Four black iron nipples, with continuous flow of untreated water
2. Four black-iron nipples, with intermittent flow of untreated water
3. Four galvanized-iron nipples, with continuous flow of untreated water
4. Four galvanized-iron nipples, with intermittent flow of untreated water
5. Four black-iron nipples, with continuous flow of treated water
6. Four black-iron nipples, with intermittent flow of treated water
7. Four galvanized-iron nipples, with continuous flow of treated water
8. Four galvanized-iron nipples, with intermittent flow of treated water.

All nipples were for standard ½-in. pipe, cut to 6-in. lengths, cleaned, weighed, and coupled together four in a row by means of short pieces of plastic tubing. The continuous flow in each case was at a rate sufficient to maintain a water velocity of about 2.6 fps through the nipples. The intermittent flow was at the same rate, but the water was turned on automatically for only 15 sec once every 15 min.

After 1 month, two nipples from each row were removed, examined, cleaned, and weighed. In each case they were replaced by two new, cleaned, and weighed nipples of the same type. After 6 months, the other two nipples in each row were cleaned and weighed, and replacements were installed. Then, after the first replace-



(*a*) (*b*) (*c*) (*d*)

Fig. 11. Coupons After Removing Corrosion Products

The coupons are: (a) *copper, from untreated Long Beach well water (coupon on left was uncoupled, coupon on right was coupled to galvanized iron);* (b) *type 410 stainless steel, from Colorado River water (coupon on left was from untreated water, coupon on right from treated water);* (c) *galvanized iron from Colorado River water (coupon on left was from untreated water, coupon on right from treated water, and both coupons had been coupled to yellow brass); and* (d) *yellow brass, from untreated Colorado River water (coupon on left was coupled to red brass, coupon on right was coupled to galvanized iron).*

ments had been in service for 1 year, they were similarly treated.

In Fig. 12 and 13 the data derived from these tests are summarized in the form of curves in which average corrosion rates are plotted against time. Each point used for establishing the curves represents the average obtained from the weight losses of the duplicate nipples.

It is interesting to note that the curves confirm the data shown in Table 2 for the black-iron and galvanized-iron coupons in that attack on black iron in treated Colorado River water is appreciably greater than on galvanized iron, whereas the rates of corrosion of black iron and galvanized iron in the untreated water are essentially the same. Also, as in the case of the test coupons, the corrosion rates of the galvanized nipples in the untreated and the treated waters did not differ greatly, confirming the fact that treated Colorado River water is not significantly more aggressive than the untreated water to galvanized iron, but that it is substantially more corrosive to black iron. The fact that the corrosion rates of the nipples after 8 months of service were higher than those of the corresponding metal coupons can be attributed to the higher water velocities in the nipple test (2.6 fps) than in the coupon test (1.6 fps).

Yellow-brass and red-brass nipples are also under test along with the black-iron and galvanized-iron, but sufficient data are not available to warrant discussion of corrosion rates.

Summary

Experience has taught that in the distribution systems of district member cities, corrosion problems can be reduced: [1] by elimination of direct connections between dissimilar metals (galvanic couples) in piping assemblies, [2] by use of insulating couplings between dissimilar metals where they must be used in the same assembly, [3] by avoiding complete softening (in domestic softener units) of Colorado River water, particularly in connection with hot water systems, [4] by elimination of zinc stars and brass sand rings from water meters, and substitution of copper or hard-rubber sand

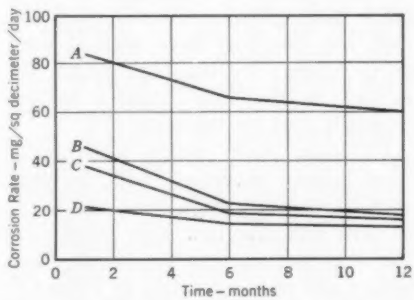


Fig. 12. Corrosion of Black-Iron Nipples in Various Waters

Data are for the following waters: A—*treated for entire test;* B—*raw for entire test;* C—*treated intermittently; and* D—*raw intermittently. The intermittent operation consisted of flow-on for 15 sec once every 15 min. The linear velocity of water was 2.6 fps.*

rings where needed, [5] by use of buffing, followed by greasing of meter parts during servicing instead of acid cleaning and rinsing, and [6] by use of sodium hexametaphosphate during periods of changing water quality.

The corrosion tests so far completed indicate that untreated Long Beach well water, a naturally soft, colored water of low mineral content and free of dissolved oxygen (but containing some hydrogen sulfide) was less corro-

sive to most of the metals tested than were the other five waters. Treated Long Beach water, freed of color and hydrogen sulfide but containing some dissolved oxygen and carrying a chlorine residual, was appreciably more corrosive than the untreated water to most of the metals tested.

Los Angeles aqueduct water, a moderately soft water of low mineral content, was distinctly more corrosive to aluminum than were the other waters. It was also relatively aggressive to black iron, galvanized iron, zinc, and lead, but this may have been at least partly caused by the high water velocities in the Los Angeles system channels used for the tests.

Colorado River water, a naturally hard supply saturated with oxygen, with a relatively high dissolved-solids content and resultant high conductivity, was particularly aggressive both before and after treatment to Type 410 stainless steel and to the anodic members of most galvanic couples. After treatment, during which the water was softened, filtered, and chlorinated, the water became markedly more corrosive to black iron and to Type 410 stainless steel, although not to the other uncoupled metal test strips.

The information gained from these and similar studies can serve as a practical guide for selection of the most resistant metals to be used with waters of known quality. It is hoped that the work herein reported will encourage other water works men to initiate corrosion studies of their own, and help manufacturers to improve the alloys used in metal parts, with the aim of reducing the tremendous annual losses caused by corrosion in the water works field.

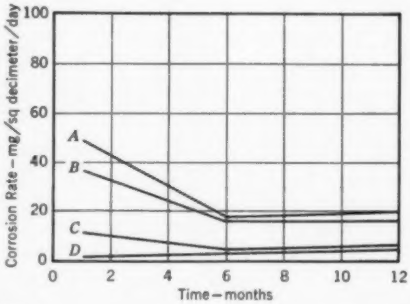


Fig. 13. Corrosion of Galvanized Nipples in Various Waters

Data are for the following waters: A—*treated during length of test;* B—*raw during length of test;* C—*treated intermittently; and* D—*raw intermittently. The intermittent operation consisted of flow-on for 15 sec once every 15 min. The linear velocity of water was 2.6 fps.*

Acknowledgments

The author wishes to acknowledge the valuable assistance received from the members of the district laboratory staff who performed the laboratory and field work which was the basis for this paper, the cooperation of the water departments of the cities of Long Beach and Los Angeles during the field test installations in their respective systems, and the cooperation of the water departments and meter shops of all the member cities for the information which they gave concerning experiences in their distribution systems.

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Effects of Softened Water on Equipment

Loring E. Tabor

A paper presented on Oct. 28, 1955, at the California Section Meeting, Sacramento, Calif., by Loring E. Tabor, Specification Engr., Dept. of Water and Power, Los Angeles, Calif.

SOME metals that do not corrode in water having considerable hardness may corrode in water that is softened. This is because the softening of water usually reduces the hardness, either by removing calcium bicarbonate and magnesium bicarbonate or by exchanging the calcium and magnesium for sodium, and it is the temporary hardness of water which is responsible for the protective scaling that forms on metal surfaces. The protection the metal might otherwise receive is therefore diminished in softened water.

In many water systems, considerable effort is made to protect pipelines from corrosion. Paints or coatings of asphalt, coal tar, or cement of various types are used, but, in some items of equipment, protective coatings are impossible because they interfere with operation. Where protective coatings are not feasible, various kinds of bronzes can be used in valves, meters, and pressure regulators. Because some of these bronzes are required to have high strength, manganese bronzes with a high percentage of zinc have been used. Water that has been softened sometimes causes dezincification of the bronze, however, and ultimate failure of the part occurs.

Los Angeles Experience

Since October 1954 the Los Angeles Water System has experienced considerable trouble with the failure of valve stems. Examination showed that the primary cause for failure was weakening of the stems by dezincification. A chemical analysis of the deposits taken off the back of one of the valve discs showed that the material contained approximately 27 per cent calcium carbonate, 24 per cent silicon dioxide, 19 per cent zinc oxide, 13 per cent ferrous oxide, and small percentages of other minor constituents. In all probability, the zinc came from the badly dezincified valve stem. Dezincification was found in high-zinc content bronzes that had been in contact with the softened waters of the Metropolitan Water District.

Los Angeles receives water from the Los Angeles River sources, the High Sierra mountains through the Owens Valley Aqueduct, and the Colorado River. The water from the Colorado River is purchased from the Metropolitan Water District, of which Los Angeles is a member. Table 1 shows the chemical analyses of the water received from these three sources.

Dezincification has occurred rather universally in cases where bronzes containing a high zinc content have been used with water that has been softened with lime and which has a high pH value. Following the failure of valve stems from dezincification, an analysis was made of the stem and the dezincified stem material. The valve from which the stem was taken

for analysis had been exposed to Metropolitan water for approximately 2 years. The results of this analysis are given in Table 2.

Water from the Owens Valley Aqueduct, the Los Angeles River sources, and the local wells was not treated in any way, except for chlorination, and occasional treatment with copper sulfate in the reservoirs. Over a period of years, almost no dezincification trouble has been experienced in these waters. When water was brought into Southern California from the Colorado River and treated at the La Verne Softening Plant of the Metropolitan Water District, however, some difficulties were anticipated. In April 1950 preliminary tests were started in an attempt to determine the effect of softened Colorado River water on various bronzes.

Sandwich Tests

Sandwiches composed of various bronzes and cast iron were made and placed in the Palos Verdes Reservoir of the Metropolitan Water District. These sandwiches were recently transferred to the Eagle Rock Reservoir, which also contains water from the Metropolitan Water District. Figure 1 is a sketch of one of these units. The bronze bolt holding the sandwich together fits fairly tightly in the bronze and cast-iron pieces but no special care was taken to insure good electrical contact between the bolt and the cast iron. There could have been considerable variation in the resistances of the galvanic cell formed in the sandwiches. The iron generally acts as the anode and the bronzes as the cathode. In this test, however, the protection provided by the iron did not entirely protect the bronzes. The test indicated that the bronzes containing the greatest amount of zinc and aluminum lost the most weight. Weight loss plotted in relationship to the zinc content of the bronze is shown in Fig. 2.

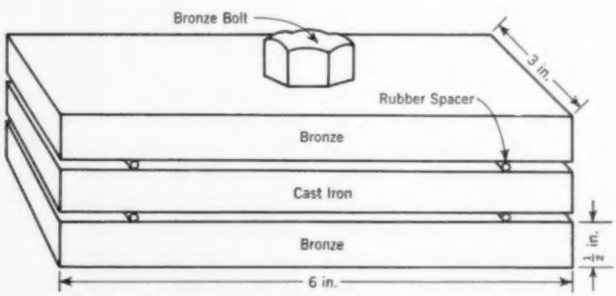

Fig. 1. Bronze and Cast-Iron Test Sandwiches

The iron acts as the anode and the bronzes as the cathode. Tests indicated that bronzes containing the greatest amount of zinc and aluminum lost the most weight.

Selective Dissolution

Selective dissolution can occur in copper base alloys, where there is a considerable difference in the electrode potential between the copper and the alloy element. Table 3 shows a portion of the electromotive force series of elements. There is quite a difference in the electromotive potential between copper (with a potential of −0.34),

aluminum (with a potential of 1.70), zinc (with a potential of 0.76), and iron (with a potential of 0.44). Iron in a direct cell could not protect zinc or aluminum from attack. It would be expected that, in alloys containing very high contents of aluminum or zinc, the zinc or aluminum would be dissipated before the iron was attacked. Because the potential difference between aluminum and copper is greater than between zinc and copper, selective dissolution would be expected to be more pronounced in aluminum bronzes than in bronzes with high zinc contents. Considerable evidence, borne out by the present experiments, indicates that there is an alloy content below which selective dissolution either will not occur, or else will be at a negligible rate. This point would be expected to be much lower in aluminum bronzes than in bronzes containing zinc. Although, in the tests reported in this paper, dezincification has not occurred in bronzes containing less than 15 per cent zinc, dealuminization has taken place in aluminum bronzes containing only 8 per cent aluminum. It is possible that selective dissolution, under certain conditions, could occur at lower percentages of the alloy.

Dezincification Factors

Some factors which affect the rate of dezincification in copper zinc alloys are percentage of zinc, electrical conductivity of the water, galvanic couples or electrical currents and other alloying components, availability of oxygen, pH value of the water, and other chemicals present in the water.

Undoubtedly, there are other factors that could influence the rate of dezincification, but under ordinary conditions in the water system, those shown above are considered to be the most important.

TABLE 1

Analysis of Los Angeles Waters

Item	Portion of Total Sample—*ppm*		
	Owens Valley Aqueduct	Los Angeles River Conduit	Metropolitan Water Dist. (as delivered)
Total dissolved residue (calculated)	216.0	377.0	650.0
Total hardness ($CaCO_3$)	88.0	207.0	125.0
Alkalinity ($CaCO_3$)	124.0	156.0	109.0
Sulfates (SO_4)	26.0	90.0	274.0
Chlorides (Cl)	18.0	31.0	80.0
Nitrates (NO_3)	0.3	5.0	0.5
Calcium (Ca)	27.0	57.0	32.0
Magnesium (Mg)	6.0	14.0	11.0
Sodium (Na)	37.0	44.0	172.0
Potassium (K)	5.0	4.0	4.0
Silica (SiO_2)	21.0	22.0	10.0
Iron (Fe)	0.02	0.01	0.02
Aluminum (Al)	0.06	0.08	0.10
Manganese (Mn)	0.005	0.005	0.008
Boron (B)	0.52	0.28	0.14
Fluoride (F)	0.6	0.5	0.4
Specific conductance (*micromhos* $\times 10^6$)	346.0	574.0	1,021.0
pH	8.33	7.76	8.35
Temperature (°*F*)	59	63	64

Dezincification seems to occur in two different ways, or, at least, two types of appearances result. One type is known as the plug type and occurs in local areas. The other is known as the uniform-layer type. It is the author's opinion that the plug type is the result of galvanic couples or electrical currents, whereas the uniform-layer type is caused by direct chemical action without the concentrating effects of galvanic or electrical currents.

Effect of Zinc Content

Generally, the higher the percentage of zinc in the alloy, the more susceptible the material will be to dezincification. There seems to be a percentage

of zinc content below which dezincification will not occur, however. Figure 2 indicates that, even with low percentages of zinc, when the zinc content is increased the loss of metal also increases. With increases in zinc content above approximately 20 per cent, however, the metal loss accelerates tremendously. The following is an explanation of what occurred in the bronze bar test:

1. In bronzes with low zinc content, the zinc and the copper act as a unit, with iron providing the cathodic protection. The lower the percentage of zinc in the bronze, the greater is the differential of the electrode potential between the iron and the bronze. This results in a greater cathodic protection by the iron.

2. In bronzes having a high zinc content, the zinc and the copper seem to act independently of each other, with the zinc being anodic to the iron and the copper having a cathodic relationship to the iron. The zinc is dissipated because iron cannot protect it.

3. Between the bronzes having a high percentage of zinc and those having a low percentage of zinc there appears to be a zone of transition. In this zone (15–20 per cent zinc) the action is partially surface corrosion and partially dezincification.

Conductivity of Water

A small primary cell was set up with water as the electrolyte and ¼-in. cast-iron and manganese bronze rods held in a fixed position as electrodes. The external current flow was measured with a zero-resistance ammeter, which is, in effect, an ammeter with a resistance compensation device (*1*). The current measurements in Table 4 were taken after the cell had stabilized and the readings had become constant. Table 4 shows that the current flow is not necessarily in direct proportion to the electrical conductance of the water.

The amount of metal changed to a salt is directly proportional to the current flow. In this test, the metal loss

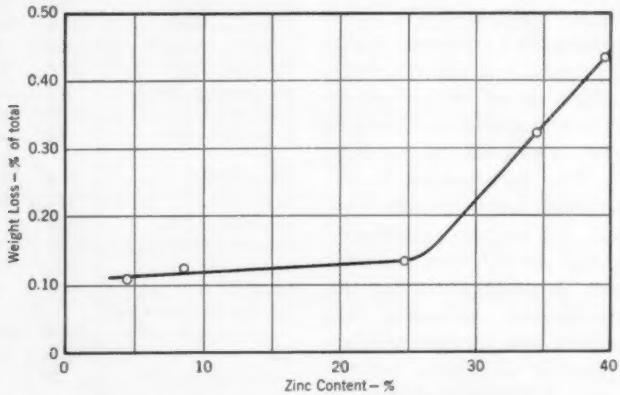

Fig. 2. Weight Loss Related to Zinc Content

Dezincification increases as the percentage of zinc in the sample increases, but there seems to be a level of zinc content below which dezincification will not occur.

in the Metropolitan water was about 4.17 times greater than that in the Owens Valley Aqueduct water, while the ratio of the electrical conductivity was about 3.38 to 1.0. The rate of metal loss in the Metropolitan water was about 2.85 times greater than that of the Los Angeles River water, and the ratio of the conductivities was about 1.75 to 1.0. The effect of the different percentages of various chemicals in the water is not generally known. Some chemicals accelerate dezincification, some retard it. Effects of chemicals in water on dezincification should be further investigated.

Electric Currents

It is impossible wholly to eliminate galvanic couples or the flow of stray currents in a water distribution system because even two different compositions of bronze will develop a couple. A primary cell, of the same size as in the previous test, was arranged, using a ¼-in. phosphor bronze rod and a ¼-in. manganese bronze rod, with the Metropolitan water acting as the electrolyte. The electrical flow with the two bronze rods was 11 μa, as compared to 2,960 μa with the one iron and the one bronze rod. The manganese bronze rod with the high content of zinc was the anode, and dezincification was probably taking place.

In double-disc gate valves, the ferrous parts of the inside of the valves are usually coated with some type of protective coating that forms a definite resistance between the iron and the water. The resistance between the valve stem and the gate body is quite low. At the same time, the resistance between the body and the discs might be relatively high. In addition, the galvanic action is influenced by the relative physical location of the various components of the valve. When a gate valve is in the open position, the stem is almost enclosed by the discs. A small test cell shown in Fig. 3 was set up to approximate the condition which occurs in a double-disc gate valve in the open position. Using a vacuum tube voltmeter to measure the potentials, 0.4 v were measured between the iron and the bronze tube before the resistances were connected. After connecting the resistances, and before the rod was put down into the tube, the potential dropped to 0.24 v. Then the rod was lowered into the position shown in Fig. 3, and the potential between the bronze rod and the bronze tube was found to be 0.22 v. The voltage of the iron forced the bronze rod to become an anode in relationship to the bronze tube. This might be compared to a large battery (that is, the iron to the bronze tube) forcing its potential on a small battery (the bronze rod to the bronze tube). In water distribution systems there is an overwhelming amount of iron as compared to the bronze in the valves, meters, and other water works apparatus. If the resistances are at all comparable to those of the test, therefore, it is often possible to have some

TABLE 2

Dezincification in Manganese Bronze Value Stem *

Materia	Original Valve Stem *per cent of total*	Dezincified Valve Stem *per cent of dezincified material*
Copper	58.0	90.0
Zinc	33.0	4.0
Manganese	2.5	0.2
Aluminum	2.0	0.4
Iron	3.0	2.0
Tin	1.0	1.0
Nickel	0.5	0.01
Silicon	0.05	0.05
Lead	0.3	0.4

* Material tested was from core of valve stem.

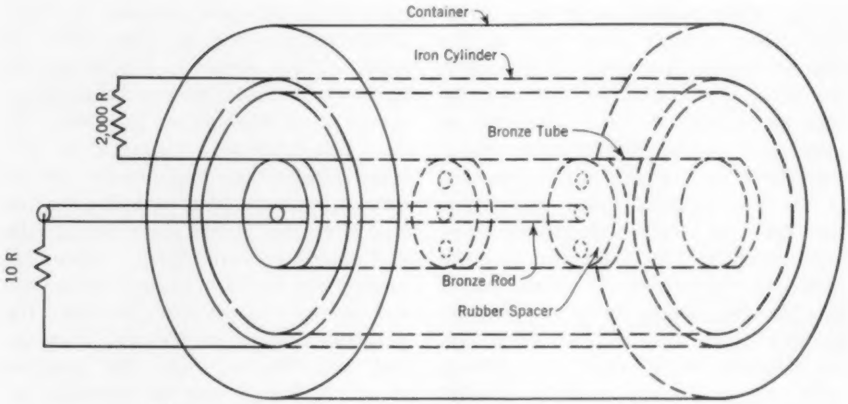

Fig. 3. Primary Test Cell Composed of Bronze and Zinc

This primary cell was constructed to approximate the conditions existing in double-disc gate valves, where the resistance between valve stem and gate body is low at the same time that resistance between the body and the discs might be relatively high.

bronze parts anodic in relation to other parts of the system.

This test demonstrated that the bronzes could be forced to become the anode and thus be dissipated. Consequently, only bronzes that are not subject to selective dissolution should be used, even when they are in an anodic relationship to other parts close to them. Nonuniformity of the materials or current flow, caused by actual construction features, would usually cause dezincification to begin at one point first. Then, in bronze, an electrical couple develops between the dezincified bronze (copper) and the unattacked bronze immediately around it. This couple would have an extremely low resistance to electric-current flow, and would cause the rapid progression of dezincification in that area. This is the explanation of the rapid development of plug-type dezincification.

Alloying Components

Bronzes often contain a number of other elements besides the major constituents. Some of these elements, such as iron and manganese, are thought to promote dezincification, while others, such as arsenic, antimony, phosphorus, and tin (*1*), are believed to retard or inhibit the dezincification. These same inhibitors are supposed to be effective in combating dealuminization in bronzes containing large percentages of aluminum. Arsenic seems to be the material used most extensively as an inhibiting agent. Research which has been made to date on the waters of the Los Angeles area has taken into consideration neither the inhibiting nor the accelerating influences of these elements.

Availability of Oxygen

Dezincification is influenced by the amount of oxygen available (*1*). In tests performed in the laboratory, the water was agitated continuously to provide oxygen. This was to simulate conditions in a water distribution system where oxygen is generally avail-

able. An absence of oxygen, therefore, cannot be depended upon to stop corrosion or dezincification.

Dezincification may take place very rapidly where there is excessive oxygen. During one experiment, a manganese bronze test rod and a cast-iron test rod happened to be left in contact with each other on a wet paper towel. The manganese bronze rod, in approximately 16 hr, showed visible dezincification on the side in contact with the wet towel. Oxygen, moisture, and galvanic current were all present to provide almost perfect conditions for rapid dezincification.

TABLE 3

Standard Electrode Potentials

Element	Electrode Potential
Aluminum	1.70
Zinc	0.76
Iron	0.44
Nickel	0.23
Tin	0.14
Copper	−0.34
Lead	−0.80

Other Factors

There is some disagreement as to the influence of the pH value upon dezincification. The waters of the Southern California area are definitely basic, and yet, in Metropolitan water, there have been dezincification problems. Some authors state that an acid condition is favorable to dezincification but it is generally conceded that lime-softened water with a high pH value will cause dezincification of most manganese bronzes. Other factors, such as the velocity of water, temperature, deposits built up on the surface of the material, and the protection provided by other materials which may act as an anode, may influence the rapidity of dezincification.

Dealuminization

In the Southern California area there is general agreement that aluminum bronzes should not be used in local waters. Approximately 2 years ago a valve company submitted a sample valve stem to the Department of Water and Power for a series of tests. Upon inquiry, the company stated that the stem was composed of silicon aluminum bronze. The stem was placed in a glass cylinder containing a carefully analyzed sample of Metropolitan water and was left for a period of 30 days. At the end of that time, approximately ½ in. of white precipitate was found at the bottom of the cylinder. This white precipitate was analyzed and proved to be aluminum oxide. It is thought by some that bronzes containing aluminum protect themselves with a coating of aluminum oxide. For some reason, however, the aluminum oxide did not protect the aluminum bronze in this test. Samples of aluminum bronzes collected from other water utilities in the area were also found to be in a very weakened state.

TABLE 4

Current Measurements

Item	Conductance of Water—*micromhos* $\times 10^6$	Shorted-Cell Current *ma*
Owens Valley Aqueduct water	325	0.71
Los Angeles River water	630	1.04
Metropolitan Water Dist. softened water	1,100	2.96

Recently, an aluminum bronze rod was placed in a glass cylinder containing Metropolitan water and the action was watched very closely. Plug-type dealuminization occurred in the bronze near the bottom of the cylinder, while general oxidation, with a coating

buildup, occurred near the surface of the water. Rapid buildup of nodules of aluminum oxide took place around the point of dealuminization near the bottom of the cylinder. It is possible that in this experiment, there was a galvanic-current flow due to the difference in the amount of oxygen near the surface of the water and near the bottom of the cylinder. The evidence from the rod, during the test, would indicate that there was plug-type dealuminization, without a protective-coating buildup strong enough to stop the galvanic currents. In most water works equipment, where high-strength bronzes are required, the protective action of any oxide coating cannot be depended upon because the oxide coatings would be destroyed very rapidly by the operation of the equipment.

Conclusions

On the basis of the tests made to date and from experiences in the Southern California area, no bronzes subject to selective dissolution should be used under any conditions.

Since high strength is a requirement in many cases, a search was made for materials to replace manganese bronzes. Various stainless steels were considered, but they were disqualified because of cost and the difficulty in machining parts. Beryllium copper was considered, but the expense was prohibitive. Silicon bronze seem satisfactory, except that the machining and handling in the foundry is difficult.

A family of bronzes * made up of copper-base alloys containing approximately 5 per cent nickel, 5 per cent tin, and 2 per cent zinc was tested. These bronzes can be heat-treated to obtain sufficient strength to replace manganese bronzes for practically any purpose. The percentage of the alloying elements in these bronzes is low in comparison to the amount of zinc in manganese bronzes, and since both nickel and tin are noble to iron, these bronzes are the logical choice. So far, tests have shown no evidence of selective dissolution in these bronzes.

The Department of Water and Power specifications for high-strength bronzes to be used in softened waters now contain a provision stating that the zinc content shall be not more than 7 per cent, and that the content of aluminum shall be not more than 2 per cent. These requirements may be quite severe, but there seems to be nothing gained by allowing more zinc or aluminum in the bronzes. If it becomes known that materials not subject to selective dissolution are excluded from competition because of this limit, the specifications can be revised to allow the use of such materials. Within the limits of the specification, and as long as the strength requirements are met, the actual choice of materials is left to the supplier.

Acknowledgment

The author is grateful to the many employees of the Los Angeles Department of Water and Power for their valuable suggestions, criticisms, and assistance rendered in determining test procedures and in the preparation of this article. He also wishes to recognize the various water departments throughout Southern California, the Metropolitan Water District, and have supplied material and information.

Reference

1. Uhlig, Herbert H. *The Corrosion Handbook.* John Wiley & Sons, New York (1948).

* The Ni-Vee bronzes used are registered in the US Patent Office by International Nickel Co., New York.

Tunnel Construction at Chicago

George S. Salter

A paper presented on Jun. 15, 1955, at the Annual Conference, Chicago, Ill., by George S. Salter, Chief Filtration Engr., Filtration Design Div., Chicago, Ill.

APPROXIMATELY 5 years from now, when it is completed, the Central District Filtration Plant will provide filtered water to about 3,000,000 people residing in the northern two-thirds of Chicago and its adjacent suburbs. It will be the world's largest municipal water filtration plant by far, having three times the capacity of the South District Filtration Plant, which is presently one of the largest and which has been operating at rates exceeding 170 per cent of its nominal capacity of 320 mgd.

The location and construction of the interconnecting tunnels between the proposed plant and the existing Chicago and Wilson Avenue Tunnel systems is one of the major items of the Central District Filtration Plant Project, the other items being the preparation of the site itself and the plant construction. This paper will deal, primarily, with the tunnels.

Chicago Water System

A brief description of Chicago's water system will be helpful in showing the functions of the proposed tunnels in the filtration plant project.

Chicago's water supply system consists of three districts, as shown in Fig. 1. Each district has a separate tunnel system (including one or more cribs in Lake Michigan) and a number of pumping stations. In accordance with their locations they are designated as the South, the Central, and the North Water Districts.

The South Water District includes that part of Chicago which lies south of the general line of 39th Street (Pershing Road). The water system for this district consists of an intake crib in Lake Michigan, the South District Filtration Plant, a 24-mile system of tunnels varying in size from 6 to 16 ft, three pumping stations, and an extensive distribution system. It furnishes clean sparkling water from the filtration plant to the more than 1,400,000 residents in the South Water District and to suburbs south and southwest of the city.

The Central Water District includes the area between 39th Street on the south and the approximate line of North Avenue on the north. This system consists of a lake intake crib, approximately 20 miles of tunnel varying in size from 6 to 16 ft, five pumping stations, and the necessary distribution system. It furnishes water to approximately 1,800,000 people, including the residents of several suburbs west of the city. This water is untreated, except for the chlorine added to assure its bacteriological safety.

The North Water District includes the city area north of the approximate line of North Avenue. The water system consists of a lake intake crib, ap-

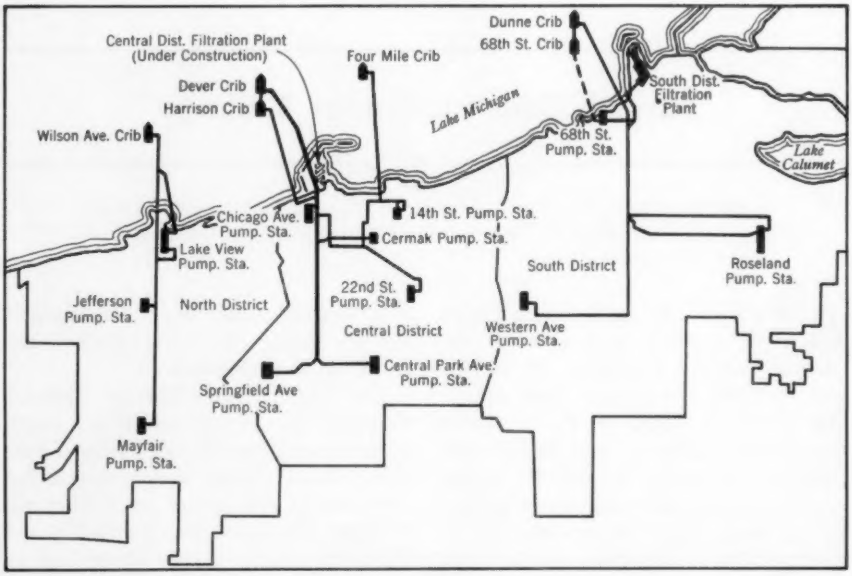

Fig. 1. Chicago Water Districts

Cribs, tunnels, existing and proposed filtration plants, and pumping stations are shown for the three districts. The boundaries shown indicate the limits of the districts and not necessarily the limits of the area served. Pumping stations are indicated by ■. The 14th Street pumping station has been permanently out of service since Dec. 31, 1954.

proximately 10 miles of tunnel varying in size from 6 to 13 ft, three pumping stations, and an extensive distribution system. It furnishes water to approximately 1,000,000 people in Chicago and several suburbs west and northwest of the city. This water is untreated except for chlorination. It should be noted that, although the tunnel systems of the three water districts are not interconnected, the distribution lines for districts are connected at numerous points. Lines of demarcation between them, however, are not exact.

South District Filtration Plant

The South District Filtration plant was placed in full operation in 1947. It consists of the usual filtration plant units—low-lift pumps, mixing basins, settling basins, filters, filtered-water reservoir, chemical building, laboratories, shops, garage, and administration building. The average pumpage for 1954 was 352 mgd, with a maximum of 539 mgd.

The construction of the South District Filtration Plant was the result of studies which began as early as 1926. Those studies led to the recommendation that the South Water District be furnished with filtered water in advance of the other districts, because the water being taken from the south end of Lake Michigan had more impurities. While the South District Filtration Plant was under construction, however, the city continued making studies to supply filtered water to the other two water districts.

Central District Filtration Plant

In 1946, consultants were retained by the city to advise on the best and most economical way to provide filtered water to the Central and North Districts. Those consultants submitted a report in December 1946 in which they recommended the construction of one filtration plant in Lake Michigan, just north of Navy Pier and east of Lake Shore Drive, to supply filtered water to the residents of both districts. Since that time, this location has become known as the Navy Pier site.

The suggested location and details of the plant recommended by the consultants were studied in detail by city engineers and by committees which were appointed by the city council. After numerous hearings and conferences, at which all parties directly and indirectly concerned with the construction of the plant were given an opportunity to present all possible arguments both for and against the proposed location, the city council approved the Navy Pier site on Nov. 29, 1949. A slight change was made from the location recommended by the consultants, the plant being moved about 500 ft eastward so that approximately 25 acres of Lake Michigan would be left between the plant and Lake Shore Drive (*see* Fig. 2). The city then submitted a request to the federal government for permission to construct the plant at the selected site and, on Jan. 19, 1951, a permit was received from the secretary of defense. Shortly thereafter preliminary construction work began on the cofferdam, the first unit of the plant. The contract for the cofferdam, however, was not let until May 28, 1952, with the contractor beginning construction on Jun. 16.

The site development requires the construction of a 6,475-ft cofferdam which will permit dewatering of the 61 acres of Lake Michian bed on which the plant will be built. The cofferdam construction consists of a combination of cellular- and dike-type constructions. The construction of the cofferdam was delayed approximately 2 years by litigation involving the right of the city to use the area for filtration plant purposes. The plant construction proper was to begin as soon as the cofferdam was completed and dewatered, which was judged to be in the fall of 1955.

The major units of the plant, in the order of their probable construction, are a dual 68-mil gal filtered-water reservoir, ninety-six 10-mgd filter units, sixteen 172-ft by 295-ft double-deck settling basins and a 180-ft by 1,100-ft intake structure, low-lift pumping station, head house, and chemical building. Approximately 400,000 cu yd of concrete will go into these plant substructures which will cover an area of approximately 44 acres. These structures will be supported on more than 100,000 piles, driven through sand into the underlying clay.

The plant superstructure will occupy an area of approximately 23 acres, consisting mostly of one-story structures over the filters, mixing basins, and part of the settling basins. The highest buildings will be in the head-house area—the pumping station and chemical building—but even here the maximum roof height will be only 62 ft above lake level, and only 40 ft above the surrounding filled area.

One of the major reasons given by the consultants for recommending the location of the plant at the Navy Pier site was the proximity of this site to

the existing Chicago Avenue tunnel system (*see* Fig. 3), and the possibility of also connecting to a second tunnel extending from the Carter Harrison Crib to an existing shaft near the lake shore. This shaft is designated as Shaft A.

The filtration plant tunnel system consists of two parts: first, the tunnels bringing raw water to the plant, and second, the tunnels taking the filtered water from the plant to the Chicago Avenue and Wilson Avenue tunnels, from where the water will flow through existing tunnels to the various pumping stations.

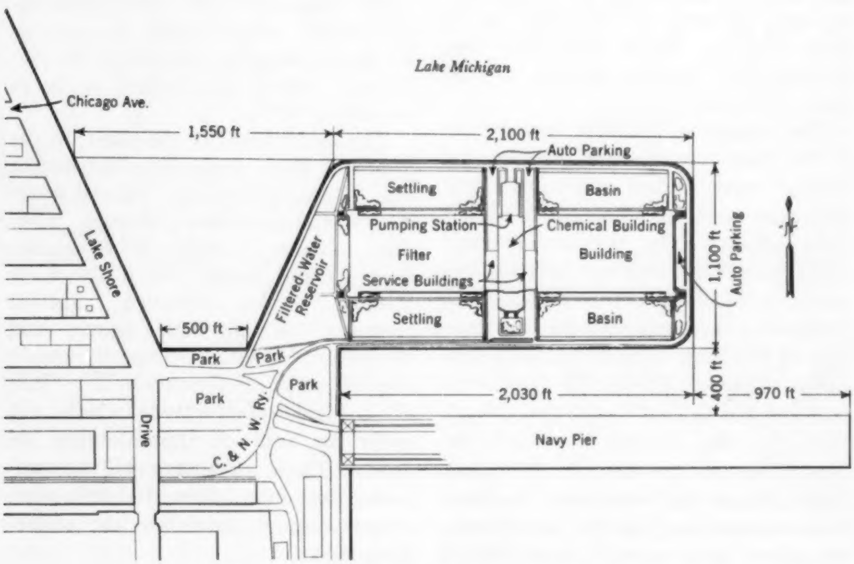

Fig. 2. Central District Filtration Plant

A change was made from the original proposed site, in that the plant was moved 500 ft further east. Dimensions shown are approximate.

Raw-Water Supply

Under normal operating conditions the principal raw-water supply for the filtration plant will be from the Dever Crib and existing 16-ft tunnel to the 20-ft tunnel which will connect the 16-ft tunnel to Shaft C1 at the filtration plant. An additional supply will be obtained from the Carter Harrison Crib by a somewhat circuitous route through the presently unused 10-ft tunnel to Shaft A and thence to the existing Chicago Avenue tunnel. The connection between the 10-ft tunnel and the 16-ft Chicago Avenue tunnel will be made just east of a bulkhead which will be installed in the latter tunnel a short distance east of the shaft at Lake Shore Drive. In addition, lake water can be taken directly into the plant through a number of gates located at the north end of the pumping-station structure.

Filtered Water

After filtering, the water will pass into the filtered-water reservoir and thence through two separate 16-ft shafts and tunnels to the Chicago Avenue and Wilson Avenue tunnel systems. A dividing wall, with its top 2-ft below the maximum water depth, will divide the reservoir into two sections. This dividing wall will make it possible to maintain the water in the north section at an almost constant elevation, while the elevation of the water in the south section will vary with the demand. This arrangement provides the optimum hydraulic conditions in the tunnel to the Wilson Avenue tunnel system, approximately 5½ miles from the plant.

With the exception of short sections of tunnels by which connections will be made to existing tunnels or shafts, all tunnel construction will be in rock, at elevations of 164–224 ft below mean lake level. The tunnels were located so as to provide a minimum of 40 ft of rock cover over the crown of the tunnel section, and a minimum of 20 ft from any other adjacent or crossing tunnel.

A 16-ft tunnel will extend from Shaft C3 in the reservoir to Shaft C4 near Lake Shore Drive and Chicago Avenue. A 16-ft tunnel, through clay, will connect the latter shaft to the existing Chicago Avenue tunnel at Lake Shore Drive. This tunnel is located at a much higher elevation than the other tunnels because of the necessity of making the shaft and tunnel connection while maintaining the Chicago Avenue tunnel in operation.

Another 16-ft tunnel will extend from Shaft C2 in the reservoir to intermediate Shaft C5, located in Lincoln Park a short distance south of the Belmont Harbor, and thence to Shaft C6 near Wilson and Clarendon Avenues. Near the latter point will also be located Shaft C7, a by-pass structure, and connecting tunnels to the existing Wilson and Clarendon Avenue tunnels.

Subsurface Explorations

Prior to the establishment of the line and grade for the tunnels connecting the filtration plant to the existing tunnel systems, a rather extended investigation was made of the subsurface conditions in the area. Part of this investigation consisted of making a series of borings, to rock, at the plant site and at a number of points along the proposed lines of the tunnels. Most of these borings were made on land, but a number were made out in the lake. A heavy steel-pipe tripod, on which the necessary drilling equipment was mounted on a platform, was used in making the latter borings.

The borings gave the rock elevations at the points selected, but there was a great variation in these elevations, and it was thought that more information would be desirable to assure the city and the contractors that there would be adequate rock cover over the tunnels at all points. It was decided, therefore, to enlist the aid of the US Geological Survey and make a sonic survey of the lake bed in the area where it was proposed to locate the tunnels.

This survey was made as a joint project by the US Geological Survey and the city. The geological survey furnished sonic devices, which had recently been developed for their work and for the Navy, and personnel experienced in the use of this equipment. The city furnished a city-owned tug, miscellaneous equipment, and a number of engineers to assist in the survey.

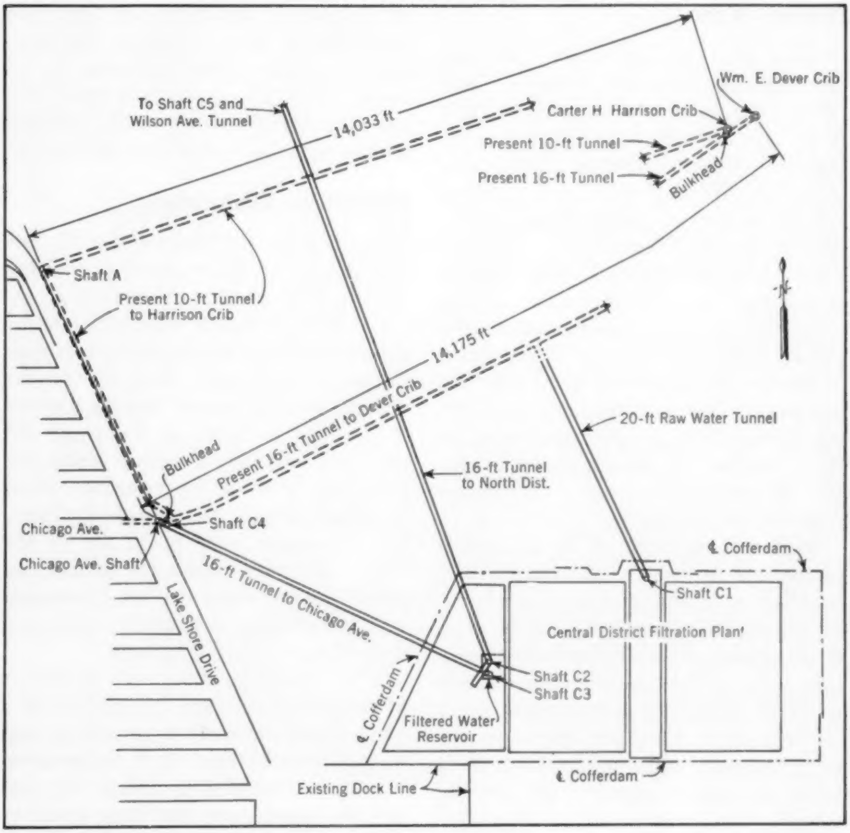

Fig. 3. Tunnel Connections

A major reason for selecting the present site of the filtration plant was its proximity to the existing Chicago Avenue tunnel.

The sonic device used in making the survey consisted of a transducer shown in Fig. 4, which is an instrument for sending out and receiving sonic signals, and a sound recorder, shown in Fig. 5, to record the reflected signals.

In operation, the transducer sent out a continuous signal and, as the tug which carried all the equipment moved over the lake area, the recorder produced a continuous strip chart on which the reflected sonic impulses were recorded. The graphs of these impulses are known as "traces." In some areas, several traces were evident on the same chart, indicating changes in density in the underlying material.

A somewhat elaborate system of controls and recording was required to obtain and record the data accurately.

First, the necessary control points had to be located in the lake and on the shore so that the tug carrying the equipment and the operating crew could be located accurately and rapidly. Second, the taking and recording of the data had to be synchronized so that the recording of the sonic impulses could be tied in with the location of the tug at the time the readings were made.

tinuous strip charts were made. The location of the tug was determined by simultaneous sextant readings by two or three readers, and these "fixes" were transmitted orally to the recorder and plotter. At the same time, the engineer in charge marked the strip chart so that the readings and the location were correlated. Numerous check runs were made over points where the

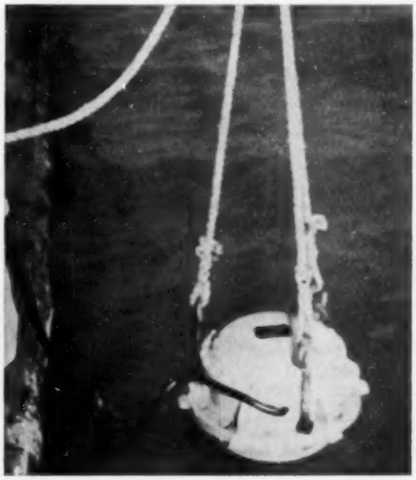

Fig. 4. Transducer Used in Sonic Survey

The transducer, shown here as it is being lowered over the side of the tugboat, is an instrument for sending out and receiving sonic signals. (Courtesy US Geological Survey.)

Fig. 5. Recording Instrument Used in Sonic Survey

The recorder produces a continuous strip chart on which are recorded the reflected sonic impulses from the transducer. (Courtesy US Geological Survey.)

A well trained crew of two or three sextant readers, a timekeeper and recorder, a signal man, a plotter, and an electronics engineer in general charge of the work, who also marked the continuous strip chart, was required to locate, record, and plot the survey.

In making the survey, the tug ran in a more or less regular pattern over the lake area where the elevation to rock was desired, and a number of con-

depth to rock had been determined by other methods in order to record known rock elevations by which to identify the rock trace. Several runs were also made so that the traces intersected, and ties between the several charts could be developed.

On completion of this field work, the chart traces were correlated with the data obtained by the borings to rock, and a rock contour map was pre-

pared, with contours at 5-ft intervals. This map covered an area about 1½ miles in width and 6 miles in length. The depth to rock below mean lake level varied from less than 25 ft to more than 135 ft, and a definite series of valleys and hills were shown. After the map was prepared, a check boring was made at the approximate center of one of the deepest valleys. Rock was found within 3 ft of the indicated depth.

struction, the tunnel work was divided into three sections, and, in order to obtain the lowest possible cost to the city, a provision was added that combined bids could be submitted on any combination of the sections, with an appropriate reduction in the unit and lump sum items.

One section includes the construction of four shafts and four lengths of tunnel near the plant site. One of these tunnels is a bulkheaded stub tunnel extending 170 ft southwest from shaft C2. Provision is made for the installation of a sluice gate in the shaft as an outlet to this tunnel. This stub tunnel will permit the construction of a third tunnel from the plant if this is found necessary in the future.

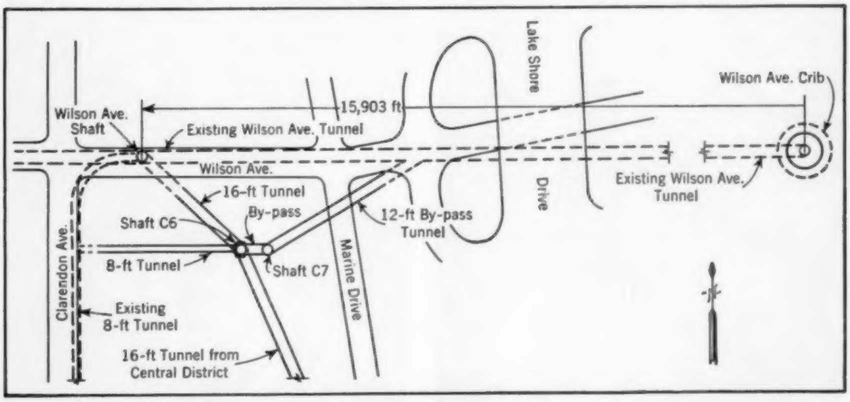

Fig. 6. Tunnel Connections at Wilson Avenue

In case of a shut-down at the Central District Plant, the by-pass facilities in the Wilson Avenue area would make it possible to supply water from the Wilson Avenue crib to the Chicago Avenue tunnel.

Tunnel Construction

The tunnel construction consists of approximately 30,500 ft of 16-ft, 1,400 ft of 20-ft, and 200 ft of 12-ft horseshoe-shaped concrete-lined tunnel in rock; 80 ft of 16-ft and 246 ft of 8-ft similar tunnel in clay; seven shafts, 14–20 ft in diameter; and a by-pass structure.

For the purpose of encouraging some of the small contracting organizations to submit bids on the tunnel con-

One section includes a shaft in the Lincoln Park area a short distance south of Belmont Harbor, and approximately 14,000 ft of 16-ft tunnel extending north and south of that shaft.

The third section includes two shafts near Wilson Avenue, a by-pass structure, and four lengths of tunnel in that area.

Plans and specifications were prepared on this basis, and bids were taken on Aug. 19, 1953. Bids were submitted by three contracting organizations on each of the three sections, and on various combinations of the sections. The lowest bid in each instance was on a combination of the three sections, with a net low combined bid of $14,843,129.40.

Shortly after bids were received for this work, an injunction on the construction of the Central District Filtration Plant at the Navy Pier site was issued by the circuit court, and all construction work was halted on the project. The city therefore rejected the bids for the tunnel work.

The city appealed the injunction to the Illinois Supreme Court and, on May 22, 1954, the court ordered the dissolution of the injunction. Shortly thereafter the city resumed work on the construction of the cofferdam, and prepared to readvertise the tunnel work. The complainants then filed an appeal with the US Supreme Court, but that court, on Oct. 18, 1954, rejected the appeal.

Plans and specifications for the tunnel work were recently reissued and bids were taken on Jun. 10. The net low combined bid was $12,696,640.00.

Tunnel Connections

Somewhat unusual procedures will be required to make the necessary connections between the new and existing tunnels. A brief description of the proposed method of making these connections is given here.

Chicago Avenue Tunnel

At the time the Chicago Avenue shaft was built, a steel-shell lining was installed in its upper portion so that a tunnel connection could be made without dewatering the shaft. Provision was also made in this shaft for installing a sluice gate at the bottom so that the section of the tunnel between the shaft and the intake crib could be dewatered. These provisions were made when the Chicago Avenue tunnel was built in 1934, with the expectation that a filtration plant would be located in this area later.

The tunnel connection between Shaft C4 and the Chicago Avenue shaft will be made as a part of the tunnel contract, but the steel-shell lining will be removed by the city. Most of the other tunnel connections will also be made by the city after the plant is placed in operation.

The shore intake, located at the north end of the low-lift pump structure, will be used during the initial plant operation period. After satisfactory operating conditions have been obtained, the filtered water will flow from the reservoir (Shaft C3) to Shaft C4, and thence into the Chicago Avenue shaft at Lake Shore Drive (*see* Fig. 3). The elevation of the filtered water will be maintained so that there will be a slight flow lakewards from the latter shaft to the Dever Crib, while, at the same time, filtered water will be supplied to the pumping stations on the Chicago Avenue tunnel system.

The sluice gate will then be installed and closed and, after the intake port gates at the Dever Crib are closed, the section of the Chicago Avenue tunnel between the shaft and the Dever Crib

will be dewatered. A permanent concrete bulkhead can then be installed in the tunnel just east of the shaft.

Connections between the existing 16-ft tunnel and the new 20-ft tunnel will then be made, as will also the necessary connections between the 10-ft tunnel along Lake Shore Drive and the 16-ft tunnel at the point just east of the bulkhead. After all connections are made, the gates at both the Dever and Carter Harrison Cribs will be opened, and the raw water will flow to the plant from the two cribs.

Wilson Avenue Tunnel

One of the most difficult of the connections between the new tunnels and the existing tunnels is the connection from the 16-ft tunnel extending northwest from Shaft C6 to the 12-ft Wilson Avenue shaft. The general layout of this connection is shown in Fig. 6.

In order to permit a connection to be made between the tunnel and the shaft, it will be necessary to construct a bulkhead in the Wilson Avenue shaft at the point where the tunnel connection is to be made. Procedures used previously by the city in making such connections consisted of installing a steel-plate bulkhead assembly with rubber gaskets at its periphery. This assembly was designed to fit closely against the curved inside surface of the concrete shaft with the rubber gaskets providing an effective seal against leakage. When installed, the assembly is wedged lightly against the wall but as the area of the wall is removed to permit the tunnel connection to be made, the water pressure against the bulkhead provides a water tight seal. After the connection is completed and the water pressures on the two sides of the bulkhead are equalized, the bulkhead assembly is easily removed.

After this connection is made and the flow of filtered water from the plant to the Wilson Avenue tunnel system has been established, it will be maintained so that there will be a slight flow in the 12-ft tunnel to the Wilson Avenue crib. A bulkhead will then be constructed in the section of the Wilson Avenue tunnel a short distance east of the Wilson Avenue shaft and then, after the port gates at the Wilson Avenue crib are closed, the section of the tunnel between the bulkhead and the crib will be dewatered. The section of tunnel connecting Shaft C7 to the Wilson Avenue tunnel will then be constructed.

During normal operations, the water supply to the Wilson Avenue tunnel system will be filtered water from the filtration plant but, in event of any failure in the filtered-water supply, it will be possible to take water from the Wilson Avenue Crib through the connecting tunnel to Shaft C7, thence through the by-pass structure between Shafts C7 and C6 to the new section of 16-ft tunnel connecting Shaft C6 to the Wilson Avenue shaft, and thence into the Wilson Avenue tunnel. This by-pass structure and the 16-ft tunnel to the filtration plant will also make it possible to supply raw water from the Wilson Avenue Crib to the Chicago Avenue tunnel system if, for some reason, this becomes necessary.

If the filtration plant were to be shut down completely and its by-pass facilities became inoperative, it will be possible to take water from the Wilson Avenue crib through Shafts C7 and C6, the 16-ft connecting tunnel to the plant, and thence through Shafts C2

and C3 to the Chicago Avenue tunnel system.

An auxiliary connection will also be made from Shaft C6, by means of an 8-ft tunnel constructed in clay to the existing 8-ft tunnel in Clarendon Avenue. This will provide a direct connection from Shaft C6 to the Lake View pumping station.

Provisions are made at the by-pass structure for the possible future construction of a reservoir immediately adjacent to that structure. With increased water use in the North Water District, it might be desirable to provide some filtered-water storage right on the tunnel system. This reservoir would fill and empty with variations in water demand.

Financing

The design of the Central District Filtration Plant is being done by the Filtration Design Division of the Bureau of Engineering in the Department of Public Works.

The construction of the Central District Filtration Plant project is being financed entirely by money received from the operation of the water works system. Water works certificates issued for its construction are retired by water revenue. No tax money is used.

For details on other phases of the project, reference is made to the article by F. G. Gordon (*1*).

Reference

1. Gordon, F. G. Central District Filtration Plant, Chicago, Ill. *Water Works Eng.*, **107** (May 1954).

AWWA Headquarters to Move

New address:

2 Park Avenue

New York 16, N.Y.

On or about April 1, 1956

Snail and Clam Infestations of Drinking-Water Supplies

William Marcus Ingram

A paper presented on Jun. 13, 1955, at the Annual Conference, Chicago, Ill., by William Marcus Ingram, Biologist, Water Pollution Control, Water Supply and Water Pollution Program, Robert A. Taft San. Eng. Center, US Public Health Service, Cincinnati, Ohio.

PUBLISHED data relating to difficulties caused by snails and clams in drinking water supplies are meager. Discussion here will therefore be concerned primarily with certain mollusks that are known to cause such troublesome conditions in potable water supplies as reduced pressure, tastes and odors, and presence of mollusks in faucet water. Thus, snail and clam problems in raw-water sources, in water treatment plants, and in distribution systems are considered. Material presented includes general discussion of troublesome snail and clam species and their life cycles, potential portals of entry into finished water, means of prevention and possible elimination of infestations, and a compilation of references from the literature.

Review of Literature

Some 30 references that relate snails to drinking-water supplies, and many more dealing with snail control in recreational waters, have been found in the literature. In substance, most of the former are articles that report snail or clam infestation associated with potable water but do not set down control measures that were applied to alleviate the nuisance.

The available literature indicates that both snail and clam infestation, as related to finished water, are of little significance in the United States at present or that, if such nuisances are experienced, resulting troubles are not commonly reported in the literature. A reporting system to indicate mollusk nuisances encountered in the water works field would produce data which would be of value in assessing the magnitude of the problems involved. Such a reporting system would be of assistance to the members of AWWA task group on biologic infestation of purified waters.

Records of mollusk infestation associated with water supply systems in the United States deal principally with one snail, *Bythinia tentaculata* (Linnaeus), which has been appropriately called the faucet snail, shown in Fig. 1. Other snails that have been reported only incidentally in association with water systems belong to the genera *Pleurocera, Helisoma, Physa,* and *Goniobasis* (*see* Fig. 1).

Baker (*1*) first reported the faucet snail from observations he made in 1898 on a water supply taken from Lake Michigan through an intake known as the Lake View crib. This supply is now incorporated into the Chicago system. He stated that the small service pipes in residences became choked and, in a number of instances, tumblerfuls of these snails issued from faucets. An investigation of

the crib revealed that screens were so coarse that eggs of this snail gained entry into the distribution system and developed there. Associated with *Bythinia* in the area of the crib were the snails *Pleurocera elevatum* Say and *Goniobasis livescens* Menke (*see* Fig. 1). Baker (*2*) again refers to the above snail infestation in his monograph on the topic of Wisconsin mollusks.

Other investigators who have referred to Baker's reference (*1*) on this snail pest in the Lake View crib are Goodrich (*3*), Berry (*4*), and Abbott (*5*). Pennak (*6*) calls *Bythinia tentaculata* the faucet snail, but does not associate it with any specific water supply. None of the above writers discuss any remedial measures that may have been put into effect to rid the Lake View distribution system of snails. Correspondence with several persons in the water supply field in the Chicago area was unproductive in producing information relative to snail control methods that may have been instituted at Lake View in 1898.

Sterki (*7*) described a faucet snail infestation of the water system of Erie, Pa., and made only slight mention of the action taken to correct it. Sterki wrote, "At the water works of Erie, Pa., where the intake is 4 or 5 miles out in the lake, about 1 mile outside of Presque Isle, the wells at the pumping station are periodically filled up with these snails [*Bythinia tentaculata*] which have to be taken out by the wagon-loads. And they are also driven through the pipes over the city, and often plug up faucets." Associated with *Bythinia* were snails belonging to the genera *Physa* and *Helisoma*. Both Goodrich (*3*) and Abbott (*5*) have made reference to the Erie, Pa., snail infestation as discussed by Sterki (*7*).

Bahlman (*8, 9*) reported "myriads of empty snail shells (*Planorbis*)," but no living snails from the clear well at the Cincinnati filtration plant. The shells were discovered when water from the uncovered clear well was run to waste during a cleaning operation to rid it of an infestation of blood-worms (*Chironomus*).

Stredwick, in 1954, reported clogging of water meters in Singapore, Malaya, by *Melania tuberculata* Muller (*see* Fig. 1) in a request by letter for information on how to control snails. In a private communication he stated that "the snails retained on the strainers increase the resistance to the passage of water until the meter is removed, either for routine changing or in response to a complaint from the consumer that his water pressure has decreased." Complaints have indicated that this snail has affected approximately 10 sq miles of the distribution system in Singapore. The water in the affected parts of the distribution system is filtered by passing through either slow or rapid sand filters. Stredwick does not present information relative to finished-water reservoirs associated with the Singapore system, nor does he give information concerning filter or pipe maintenance troubles previous to the snail infestation of the distribution system. Abbott (*10*) reported that a relative of this snail, *Melania granifera* Lamarck (*see* Fig. 1), is found as an introduced species in Lithia Spring, Fla.

In a later letter (1955), Stredwick presents information that indicates that *Melania tuberculata* Muller snails were only abundant in that part of the Singapore distribution systems containing water that had been subjected to simple sedimentation, rapid gravity filtration, and chlorine ammonia treatment. He

states that parts of the distribution systems which were supplied with water subjected to chemical coagulation and rapid sand filtration were found to be "substantially free of snails." He concludes: "This appears to indicate that a certain minimum content of organic material in the water is essential to support the life of the snails, and, if the organic content is kept below this minimum requirement by suitable treatment, trouble with snails is unlikely to occur." Stredwick reported in his earlier letter that the meter-clogging difficulties caused by snails in 1954 had been alleviated by systematic main flushing. Flushing was carried out once a week for 2 months until snails were reduced from 56,000, at one flushing operation, to 200.

In Europe, the zebra clam or zebra mussel, *Dreissensia polymorpha* Pallas, has been recorded in the literature from 1886 to 1952 as the principal trouble maker among mollusks that have been associated with potable-water supplies. This clam is not found in the United States, but one of its relatives, *Mytilopsis leucopheata* Conrad, occurs in the southeastern states from Maryland to Florida. This clam has not been reported as causing troublesome conditions in potable-water supplies.

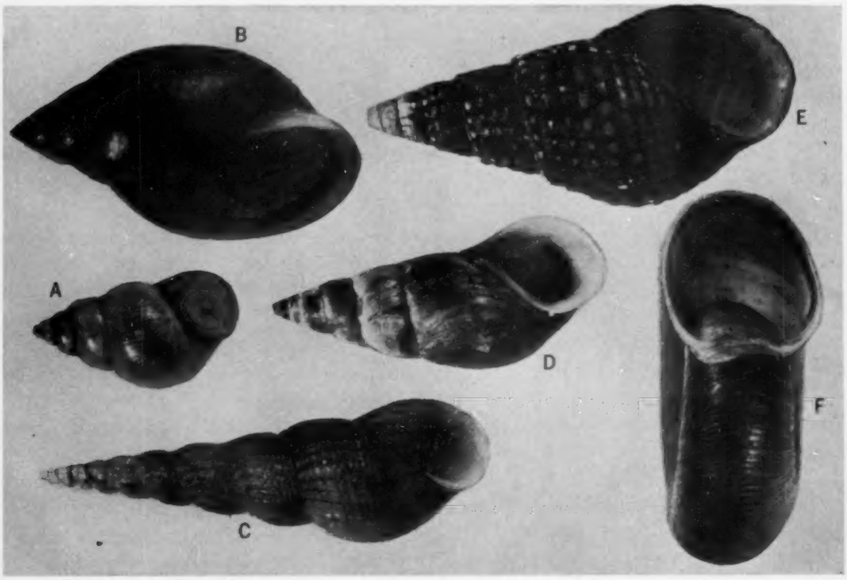

Fig. 1. Common Snails Found in US Water Systems

Bythinia tentaculata *or faucet snail, A, is the most common snail found in water supply systems in this country. The other snails shown have been reported only incidentally. They are: B*—Physa gyrina *Say. C*—Melania tuberculata *Muller; D*—Goniobasis livescens *Menke; E*—Melania granifera *Lamarck; and F,* Helisoma trivolvis *(Say).*

The earliest paper that reports the zebra clam as a nuisance in distribution mains is that by Kraepelin (*11*) which

discusses the water supply of the city of Hamburg in 1886. In that year the Hamburg supply consisted of raw water drawn from the Elbe River into reservoirs, from which, after brief storage, it was directed into the distribution system, treatment being left to the consumer. Quite naturally, many pipe growths that are well known to the water works profession became established in the system, with two mollusks, the zebra clam (*Dreissensia*), and the faucet snail (*Bythinia*), commonly occurring. Other mollusk genera that were represented were *Physa, Lymnaea, Helisoma, Ancylus,* and *Sphaerium.* Kraepelin collected 50 genera of animals from the distribution system. After slow sand filtration was established, organisms gradually disappeared from the mains.

De Vries (*12*) stated that since 1887 he had observed zebra clams growing in covered canals of the raw-water system of Rotterdam, but had never seen mussels on the downstream side of slow sand filters.

Clarke (*13*) wrote about nuisance problems caused by zebra clams in Berlin. He states, "In November 1895 a putrid taste was noticed in the water of the northern and western districts of Berlin. Samples gave high counts of bacteria and indicated that the cause must be decaying animal flesh at the Tegal works. Careful examination of the works showed the suction mains from the lake to be occupied by hundreds of thousands of mussels. The works had been shut down for 27 days previous to the outbreak, causing the death and decay of the mussels due to lack of oxygen. The trouble was eliminated by scraping the pipes, and the works went over to deep well water in 1901 so that no more trouble was experienced."

In the discussion of Chapman's paper (*14*), the following comment relative to mussels in water supplies is made: "With regard to growths, he had seen in his time tons of mussels taken out of one of the unfiltered water mains connected with the Thames supply, and, in hot weather, unless they were very quickly disposed of, they became very offensive."

Wilhelmi (*15–17*), who studied zebra clams in relation to difficulties at hydroelectric plants rather than water treatment plants, suggested using chlorine as a molluscacide and screens of small mesh to reduce clam problems. His work indicated that clams over 5 mm in length could resist "chlorine concentrations of 50 ppm for 1 hr." Screens that Wilhelmi worked with, as did Roach (*18*), were not of small enough mesh successfully to block the 0.185-mm larvae of the zebra clam.

Stilgoe (*19*) presents general information on the zebra clam in relation to filtration plants of the Metropolitan Water Board, London, stating: "Fresh water mussels (*Dreissensia polymorpha*) . . . attach themselves to the masonry, ironwork, etc., of the storage reservoirs and to the inside of the pipes leading therefrom. They congregate in layers and clusters but appear to be unable to exist in the outlet pipes leading from the reservoirs to the filter beds for a greater distance than about a mile to a mile and a half, probably because in that distance their food supply has become exhausted either by themselves or defunct because of want of light. At the mouth of the pipe the layers may be several inches in thickness, tapering to nothing at a distance. I have indeed found the bore of a 36-in. diameter pipe to be reduced to 12 in."

Hastings (*20*) states merely that zebra mussels have been known to

cause considerable trouble in water works, and that in 1886 "the zebra mussel encrusted large areas of the pipes" in the water distribution system of Hamburg.

Hobbs (*21*) only makes reference to the zebra clam in a table entitled "Organisms Reported as Having Caused Difficulties in British Waterworks," under a column headed "Growth in pipes, filter-drains, etc."

The most comprehensive published paper dealing with zebra clam nuisances is one written by Clarke (*13*). This paper discusses various remedial measures that were applied in the years 1944–50 to eliminate clams from raw-water mains and a settling reservoir located ahead of filters at the Great Yarmouth, England, water plant. The Great Yarmouth raw-water source is the Bure River, from which water is pumped through 9 miles of a 24-in. diameter main to an open sedimentation basin of 20-mil gal capacity. Water is pumped from the basin through a ½-mile 24-in. diameter main and delivered to rapid sand filters. No trouble with zebra clams had been experienced in the raw-water supply system for 40 years prior to 1944. In 1944, however, clams were found in a 5-in. thick layer in the effluent main from the reservoir, "decreasing to negligible numbers 400 yd distant." The main was taken out of service, divided into nine sections, and scraped and brushed free of zebra clams. To facilitate subsequent maintenance, the cut lengths of pipe were rejoined with removable couplings. No trouble was experienced with clams until a loss of head through the main in 1947 showed them to be present again. As an experiment, one section of main was removed and filled with a commercial compound to give a 50-ppm chlorine concentration. After 3 days an examination showed that most of the zebra clams were dead and that scraping would be required to remove them. In the 1947 infestation, 20 cu yd of zebra clams were scraped from 300 yd of this 24-in. main. In 1950, chlorine, at a 50-ppm concentration, was applied to the main continuously for 13 days and then flushed, with "mussels being discharged in their shells in great numbers." After flushing, the chlorine treatment was immediately repeated for another 6 days, with but a few mussels appearing in the second flushing.

An inspection of the 9-mile main carrying raw Bure River water to the reservoir in 1947 showed that in certain areas there were 150 zebra clams per linear yard of pipe. Costs of removing and scraping 9 miles of pipe seemed prohibitive. As an alternate, chlorine, at a concentration of 20 ppm, was introduced at the influent end of the main until "a residual of not more than 7 ppm [was] . . . obtained at the reservoir end after 3 days." After 7 days' contact, the water was flushed to waste at the rate of 200,000 gph until zebra clams were no longer discharged. Clarke (*13*) states that "two years later [1949] this main was chlorinated again to give a residual of 20 ppm and was left shut for 10 days. When it was flushed, no mussels were washed out and inspection of the interior of the main at each end of the line has revealed that it is now entirely free of all growths, thus showing the effectiveness of chlorine." In discussing methods used to remove mussels from the raw-water reservoir, it is stated that scraping and brushing with a solution containing 50 ppm of chlorine removed most, but not all, of the mussels.

Clarke (*13*), in the conclusion of his paper, discusses general methods that might be used to remove zebra clam

growths in water mains and reservoirs, including scraping, drying, treatment with chlorine, reduction of dissolved oxygen, and biological control. Under a section on prevention of clam growths, he briefly discusses filtration, chlorination, and protective coatings.

European references to snails and clams other than the zebra clam, associated with drinking water supplies, are quite general. Chapman (*14*) vaguely refers to snails found in the distribution system of Hamburg when that city's supply was untreated Elbe River water. Harmer (*22*) makes reference to the mollusks reported in the Hamburg distribution system by Kraepelin (*11*) and refers to two papers by Kemna (*23, 24*) that list mollusks from the distribution systems of Paris, France, and Ypres, Belgium. Feliksiak (*25*), in Poland, has written a generally systematic paper on mollusks which also includes information on some other organisms that are associated with water treatment and distribution installations. It is not basically concerned with control measures, nor with the magnitude of nuisance problems caused by mollusks. Hastings (*20*) refers to a duck-mussel, *Anodonta anatina,* and to freshwater snails of the genus *Lymnaea* as being generally present in water works, but of no importance usually in creating nusance conditions.

Pipe-dwelling Snails and Clams

Conceivably, most aquatic snails could enter water treatment installations and distribution systems at several stages in their life cycle. The lack of reported difficulties, however, may indicate that they seldom enter in great enough numbers to become troublesome. Because *Bythinia tentaculata,* or faucet snail, is apparently a potential nuisance, it is selected to illustrate the life cycle of a snail. *Dreissensia polymorpha,* being the foremost clam pest of water supplies, is used for the life cycle portrayal of a clam.

A large adult *Bythinia* has a shell 11 mm long by 6.5 mm wide, consisting of 5.75 whorls. Many adults have shells no larger than 8.0 mm long by 5.0 mm wide. Lengths and widths of various growth stages measure downward from these figures to 1 or 2 mm in breadth and length. Females deposit previously fertilized eggs in clusters, commonly on the shells of neighboring snails. A cluster may contain from four to seventeen eggs, the egg capsule being 1 mm in diameter. Young snails emerge from the egg capsule 2–4 weeks later, and may gain maturity in their second or third summer. Baker (*2*) reports this snail as being particularly fond of filamentous algae. It also feeds on algal and bacterial films covering bottom sand, mud, and stones.

Korschelt (*26*) and Weltner (*27*), in investigating the life cycle of *Dreissensia polymorpha,* demonstrated that this clam, unlike most fresh-water species, produces free-swimming larvae from eggs fertilized outside the body of the adult. A larva is about 0.18 mm across and the ciliated velum gives it the appearance of a rotifer. The larvae swim for approximately a week and then, coincident with the development of a foot, they sink to the substrate and adopt crawling locomotion. They next attach themselves firmly to the substrate by an attachment organ, the byssus, formed by horny threads secreted by the clam, and become fixed. During the first year they may attain a length of 5–10 mm. An adult shell measures 31 mm. Wesenberg-Lund (*28*) and Clarke (*13*) have also studied the life cycle of this clam.

Frenzel (*29*) has indicated that the zebra clam feeds on microscopic silt of vegetable origin. Additional food may consist of microscopic plants and animals that the clams are able to trap in slime secretions.

Based on respiratory structures, the aquatic snails can be divided morphologically into lung-breathers and gill-breathers. Thus, one can expect living gill-breathing snails, such as the faucet snail, to be the ones most commonly causing nuisances in distribution systems where atmospheric oxygen is not available. Empty shells of either type could be carried into distribution systems to cause reduced flows through water meters. It has been shown by Cheatum (*30*) and others that certain species of lung-breathing snails belonging to the genera *Lymnaea, Physa,* and *Helisoma* can survive extended periods submerged in water where atmospheric oxygen is not present for respiration. Data are not available, however, to indicate that it is possible, under such a condition, for lung-breathers to carry on reproduction for producing the myriads of individual snails which might lead to the clogging of distribution systems and which, on death, would produce tastes and odors.

Some common North American gill-breathing snail genera in addition to *Bythinia* are *Amnicola, Pleurocera, Goniobasis,* and *Viviparus.* If trouble arises from snails and the genera and species are unknown, an expert should, of course, be consulted, but the gill-breathers and the lung-breathers can be generally distinguished because the gill-breathers have a horny or calcareous operculum, or door (*see* Fig. 1A), that closes the aperture of the shell.

All fresh-water clams are gill-breathers. Compared to other fresh-water clams, however, the zebra clam, *Dreissensia polymorpha,* appears to be better adapted for living in pipes where there are high water velocities. This is because it possesses an attachment organ, the byssus. Most species of fresh-water clams lack a byssus, and many must depend on parasitizing various fresh-water fish during a period of their life cycle to attain adulthood.

Points of Entry Into Supply

From previously cited data, it is evident that certain nuisance-causing mollusks may enter drinking-water supplies from a river or lake which serves as the raw-water source. Troubles usually appear prior to filtration, or have been associated with distribution systems where water was not filtered before being delivered to the consumer. The mere presence of mollusks that have moved into settling reservoirs, flocculators, and clarifiers should not be looked upon as a forecast of difficulties. Several species of the snail genera *Physa, Lymnaea,* and *Helisoma* are adapted residents of the sides of such basins, and here they feed on certain algae that are sessile, as *Phormidium, Cladophora,* and *Gomphonema,* and which may give the basin sides a green or brownish color.

At this time the route which snails may use to get into finished water that has been filtered is largely speculative. Shrinkage and cracking of the sand in filter beds, as described by Babbitt and Doland (*31*), could allow snails access to the bottom of a filter, and from there they could move into finished-water reservoirs and distribution pipes. These authors state that "the effect of . . . shrinkage of the filter bed is to permit dirty matter to penetrate deeply into the bed, even into the gravel, and to impair both the washing of the filter and efficiency of filtration." These writers, in reference to mudball for-

mation in filter beds, also pose a situation whereby snails might conceivably get through filters and into finished water. The dumping of fish bowls containing snails into open finished-water reservoirs presents another possible way of snail entry.

It is conceivable that snails might enter open finished-water reservoirs under their own power. Often such reservoirs are located in parklike areas where small streams and roadside ditches with flowing water support snail populations. From such aquatic environments, snails could move into neighboring potable-water reservoirs. Snails could also enter finished-water mains and pipes that are being repaired along ditches containing water that certain species of *Physa,* for example, naturally inhabit. It was only recently that a 30-in. water snake was removed from a household service pipe in response to a complaint of "no pressure" (*32*). The anonymous author, who recorded the above instance of pipe stoppage, wrote "We won't comment on the possibility that it entered the system when new mains were being laid in the neighborhood."

M. E. Flentje, by letter in 1954, has indicated a specific route that the crustacea, *Daphnia* and *Cyclops,* took to get into water that had been filtered, thus solving finally the mystery of how these animals were appearing. Such a route also could have been taken by mollusks. He stated: "We finally discovered that there was an old loss-of-head tube which allowed settled water to pass from on top of the filters directly into the filtered water, through which crustacea could readily pass into the finished water. Correction of this condition has eliminated this trouble [*Daphnia* and *Cyclops*] in finished water."

Prevention of Entry

Control of mollusk infestations of finished-water supplies can be accomplished by chemical coagulation, filtration, and watchful filter maintenance, provided that water is carefully stored thereafter. When supplies are delivered to the consumer without filtration, potential mollusk troubles can be minimized by locating the crib structures and other types of intakes in deep water away from shoal areas that are usually most productive of mollusks. When this is not possible mechanical raking in shallows can effectively remove plant growth that snails may feed on, such as the filamentous algal forms *Spirogyra* and *Hydrodictyon* and higher aquatic plants such as *Elodea.* Once deprived of a food supply, snails will desert such barren areas. Excelsior or excelsior-and-sponge filters placed over reservoir outlet pipes, as Flentje (*33*) has indicated for prevention of Chironomids and Crustacea in distribution systems, should likewise be effective against snails.

Covering finished-water reservoirs will preclude chance entrance of snails from neighboring aquatic habitats. Construction of adequate fencing around open reservoirs will also minimize the introduction of snails by man. In repairing mains and distribution pipes along roadside ditches that are habitats for snails, care in pipe handling could prevent the chance entry of snails into distribution systems. Chemical application for control of mollusks, as a part of the routine water treatment operation, does not appear to be warranted if the above precautions are taken as preventive measures.

Elimination of Mollusks

To eliminate mollusks such as zebra clams completely from distribution

systems, go-devil scraping devices and flushing would have to be employed to rid pipes of shells, even though chemical treatment might result in successful kills. The attachment organ of this clam, the byssus, would still hold many shells in place. After death of the snails, shells would remain to impair flow in house connections and at meter strainers. Flushing could remove many snail shells from the distribution mains, if chemical treatment were successful in killing them, but would shift the problem to household water lines, where it would have to be handled on an individual basis. As described earlier, flushing alone can remove a great proportion of living snails from their resting places in distribution mains. The increased velocities accompanying the flushing also serve as an effective force in making them lose their holds on piping.

Chlorine and certain copper compounds such as copper sulfate are the only chemicals that current water treatment practice would allow to be put to use as molluscacides in drinking-water supplies. The recommended limitation on use of the latter is delineated in *Drinking Water Standards* (*34*) which states that copper as Cu should preferably not occur in excess of 3.0 ppm in treated waters. Copper compounds, as they have been variously applied as molluscacides in Michigan and Wisconsin, may be effective in reducing snail populations within the stated concentration limit. Chlorine, to be effective in clam elimination as related to British experiences, would make water unpalatable and would necessitate taking a system out of operation temporarily.

At this time, too little is known about toxicities of the newer molluscacides, such as sodium pentachlorophenate (*36*), to think of using them for prophylactic treatment or eradication of mollusks in finished water. To date, the principal use of sodium pentachlorophenate as a molluscacide has been in schistosomiasis control programs for eradication of snails carrying intermediate stages of human blood flukes. For flowing streams, Wright and Dobrovolny (*35*) report that "in most of the streams, the chemical was most effective in the area down to 1,000 ft below the site of application, indicating the intervals at which application should be made. It was also found that sodium pentachlorophenate is usually most effective when applied at concentrations of at least 10 ppm. On the other hand, concentrations exceeding 20 ppm applied for 8 hr or more did not enhance the molluscacidal effects of the compound. The effectiveness is a function of time of application as well as of concentration. Thus, concentrations as low as 2 ppm maintained for 40 hr were about as effective as high concentrations for 8 hr."

It is not feasible at this time to recommend dosages of either chlorine or copper sulfate that might be perpetuated in the literature as a standard for chemical control of mollusks in finished water. It is well known that between mollusk species, and even between populations of the same species, there are differences in toxicity thresholds to various substances under controlled conditions. Of even greater significance are variations in chemical quality, water temperature, algal abundance, amount of sunlight, and structural differences in finished-water reservoirs and distribution systems, which would preclude the setting down of a dosage figure for those chemicals that could kill mollusks under all circumstances.

If either chlorine or copper compounds are to be used as control agents, only jar tests using finished water with the specific mollusk troublemaker as the bioassay animal would specifically and economically present realistic figures for molluscacidal application. If a copper salt, such as copper sulfate, is selected as a molluscacide for use in reservoirs, it should be applied at the bottom, thus assuring immediate contact with mollusks. If it is applied at the surface, much of its effect can be lost because it is taken out of water by hardness or by adsorption on algae cells.

If mollusks are killed by chemicals, tastes and odors will invariably result, especially in the confines of distribution pipes. Decaying mollusks are extremely odoriferous, as is well known to those who have smelled "ripe" oysters or a household aquarium in which mollusks have died. Another difficulty that should be foreseen is the possibility of passage of gelatinized body fragments through the $\frac{1}{16}$–$\frac{3}{32}$-in. openings in meter strainers into and through household fixtures.

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Biologic Infestation at Indianapolis

M. P. Crabill

A paper presented on Jun. 13, 1955, at the Annual Conference, Chicago, Ill., by M. P. Crabill, Mgr. of Operations, Indianapolis Water Co., Indianapolis, Ind.

TASK Group 2670 P has the assignment of studying biologic infestations of purified water. This group was formed in 1954 as a result of correspondence which the Association received concerning infestation.

Indianapolis, for example, reported an epidemic of Copepoda in the distribution system during January 1953 and again in 1954. The Copepoda were first discovered by consumers on dead-end mains, but were later found to be abundant in hydrant samples collected from many dead ends. In Singapore, thousands of snails (*Melania tuberculata*) were retained on strainers ahead of household meters, restricting flows until consumers complained of inadequate service. In Norwich, England, an infestation of *Nais* worms provoked a violent reaction among water users (*1*). These and similar experiences in other plants indicate the need for investigating infestations and for developing practical methods of control.

Infestations are not new, but it now appears either that they are occurring more frequently, or that they are more commonly recognized and reported. In either event, it is an indication that the water works operators want to discuss the problem and are interested in discovering its source and the practical methods of control.

Sources

Structure faults which permit insects to deposit their eggs directly in purified water may be responsible for infestations. Open reservoirs on the distribution system are an invitation. The chironomid fly, one of the more common offending insects, frequently gains access through broken ventilator screens, open meter piping, or by some other such simple method. The chironomid fly may also gain entrance through filter sand when inadequate backwashing fails to remove larvae which have burrowed into the sand. Usually, however, infestations occur because some species in the raw water survives the plant chemical treatment, gaining access through the filters in the same manner as water.

Many of the smaller one-celled algae are regularly recovered from filter effluents when they are in the water applied to the filters. *Cyclotella* and *Cocconeis* forms are recovered from the distribution system flushing samples as well as from filter effluents. In spite of the absence of sunlight, some varieties seem to survive and multiply inside the mains. They are, however, so small that, unless a taste or odor problem results from their presence, an infestation of this sort may not be recognized by the consumer.

Indianapolis Infestation

In Indianapolis, the Copepoda infestations occurred in 1953 and again in 1954. In a tap sample it is easy to observe the adult Copepoda, either *Cyclops* or *Canthocamptus,* because they measure from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. long. Because of their characteristic swimming motions, too, they are likely to attract attention. Adult *Cyclops* and *Canthocamptus* are shown in Fig. 1 and 2. In 1953 the predominant species of Copepoda was *Canthocamptus.* In the following year, *Cyclops* outnumbered the *Canthocamptus.* To the consumer there is little difference in the two when observed in drinking water.

It is significant that in both years the infestation occurred only in that part of the system served by the Fall Creek plant. The balance of the city, served by the White River plant, was entirely free of Copepoda. The Fall Creek plant obtains its water from Fall Creek, on which a 7-bil gal impounding reservoir exists 10 miles upstream of the plant intake. No storage exists on the White River source. Both the 1953 and 1954 infestations were preceded by a drought period during which the reservoir was drawn below dam level and the discharge was being carefully regulated to conserve water. During the same years, the flow in the White River stream was relatively low, but sufficient fluctuations in levels occurred to move water in and out of the bayous along the river. Sampling of both streams at the plant intakes disclosed that Copepoda were present, but, while they remained low in the White River stream, there was a gradual increase in their numbers on the Fall Creek stream below the reservoir discharge. The normal counts on Fall Creek indicated zero to one Copepoda per liter, with a count of one in most samples. The increased count recorded fifteen per liter on the Fall Creek stream, with the White River stream never recording more than one. When raw-water counts increased, sampling of filter sand was started to determine the number of Copepoda being applied to the filter and to observe the effects of plant treatment on them. During several months of sand surface sampling, no live Copepoda were found on top of the filters. At the peak count, 250 dead adult Copepoda were observed per square inch of filter surface. The 250 count is not related to volume of water passing the filters. It represents the total accumulated adults per square inch of sand surface between washes. Only a negligible number of the adults found in the raw-water samples were dead.

Live Copepoda collected from raw water were transferred into a raw-water sample which had been filtered in the laboratory to remove the specimens normally present. This sample was then treated with the normal plant chlorine application, which was found to kill both the *Cyclops* and *Canthocamptus* adults in about 4 hr. The normal chlorine application at the plant is 4–5 ppm to obtain a free available chlorine residual of approximately 1.2 ppm after 45 min contact. At the end of an additional $2\frac{1}{2}$ hr in plant, the residual decreases to 0.8 ppm at the time the water is applied to the filters. The laboratory and plant evidence is conclusive that chlorine applications of this magnitude with sufficient contact time will kill the adult Copepoda.

Many of the dead adults which were found on the filter surfaces carried egg

sacs. The egg sacs, when detached from the adult and incubated at 20°C in the laboratory, hatched into the *Cyclops* or *Canthocamptus.* It is almost impossible to get an accurate count of the individual eggs contained in one sac, but they seem to vary between seven and twenty in the *Cyclops,* and the *Canthocamptus* seems to carry more than twice that number. Neither the *Cyclops* nor *Canthocamptus* egg sacs were injured in any way, even though the adults carrying the sacs were killed by the chlorine application. The smallest of the individual eggs measured 3–4 μ in diameter, with some of them being more than twice that size. At the time the largest number of adults were observed on top of the filter sand, 22 egg sacs per square inch of filter surface were counted.

Filter Effluent Sampling

Following this observation, sampling of filter effluents was begun and individual eggs were immediately recovered. At no time, however, was an egg sac found to pass the filter intact. Egg counts on filter effluents disclosed that as many as twenty individual eggs were present in each liter when the greatest number of sacs were observed on top of the filters. At other times during the infestation, three to five individual eggs per liter were recovered. The lower count corresponds to an observation of five to eight egg sacs per square inch of filter surface. Eggs collected from the filter effluent sampling were also incubated and hatched into both the *Cyclops* and *Canthocamptus.*

The sampler used on the filter effluent was a small filtering funnel into which about 1½ in. of Sedgwick Rafter sand had been placed. The filtered water was delivered through a constant head device which permitted about 100 ml of sample per minute to pass the filter. It was operated continuously between filter washes. At the conclusion of a sampling run the sand was removed from the sampler, agitated in a beaker of water, and microscopic observation was made on the specimens which had been washed free of the sand. At no time during the 3 or 4 months of continuous filter effluent sampling were any of the Copepoda observed to pass the filters in the adult form, and at no time were Copepoda found to be alive on the filter surface. The evidence demonstrates conclusively that the beginning of the infestation—in Indianapolis, at least—occurred as a result of eggs passing the filters, lodging in the distribution system, and eventually hatching, so that the adult forms were carried to the consumers.

Treatment

The specimens emerging from the eggs would undoubtedly be killed in the distribution system if chlorine residuals of the same magnitude as in the plant could be maintained. This is not practical in Indianapolis water because it would require residuals in the plant effluent higher than the public would tolerate. Certain sections of the distribution system could be isolated and a similar treatment given to that area while the consumers were not using the water, but such a method would leave the eggs unharmed. Other laboratory experiments demonstrated that if sodium chloride were added to increase the chlorides to 150 ppm, both species of Copepoda would be killed as they emerged from the eggs in ap-

proximately 48 hr. Obviously, continued flushing during a period when eggs are being carried into the distribution system is another method by which they can be removed, or at least reduced so that they are unlikely to permit an infestation which the consumers might observe. Nothing has been found, however, that will penetrate the egg sac or the individual egg and prevent it from rupturing and giving up a very healthy and active organism.

On the basis of laboratory work, it appears that the copper-chlorine-ammonia treatment, if applied to obtain a copper residual of 3 ppm and a combined chlorine residual of 0.5 ppm, will kill the adult in less than 5 hr. Copper-chlorine-ammonia having 2 ppm copper residual is equally effective in 12 hr and, having 1 ppm copper, in 24 hr. The combined chlorine residual remains 0.5 ppm in all three copper strengths and kills the species as it emerges from the egg. This seems to be a very practical method of controlling an infestation of Copepoda and, if continued over a long enough time, should eventually prevent the growth of any adults in the system.

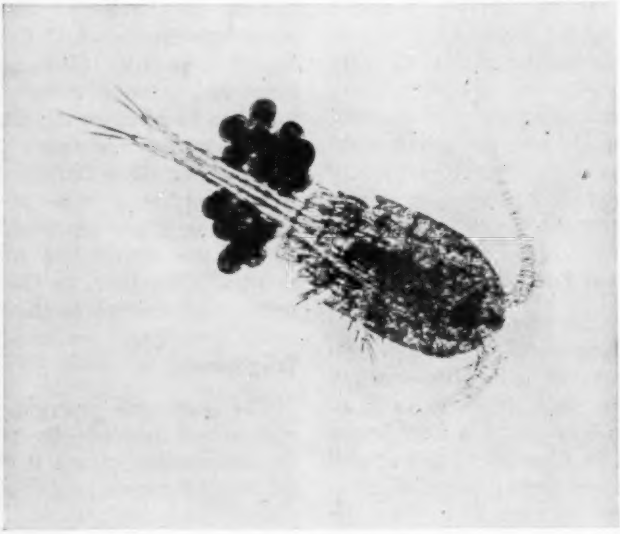

Fig. 1. Adult *Cyclops* With Egg Sacs

The dark masses at the base of the tail are the egg sacs. The photographs are approximately 75 times actual size.

It has been found that the egg sacs are sometimes continuously deposited on the filter surface for a period of not less than 10 weeks, which indicates that the one-shot method of copper-chlorine-ammonia treatment, unless repeated frequently, would not be effective. Neither is a single flushing effective if the applied egg sacs continue

after the flushing time. In 1953, two flushings were made in the Fall Creek plant system for this very reason.

During the work in the laboratory on the Copepoda, it was observed that Rotifera are also killed in the normal plant treatment before water is applied to the filters, but they too were recovered as eggs in passing the filters, and were later hatched in incubation. The Rotifera are also killed by the copper-chlorine-ammonia treatment. Although no special identification was made of the several worms that were recovered from the distribution system flushings, it was found that the *Nais* worm is killed by copper-chlorine-ammonia treatment. Water fleas are also readily killed.

The copper-chlorine-ammonia treatment was first developed in London by Alexander Houston and used as an algaecide. It was introduced in Indianapolis as an algicide before the Fall Creek treatment plant was in service, and has proved very satisfactory for that purpose. In the light of the present study, it appears to have a much greater potential than the uses to which it has been put, and seems to be the most practical method of controlling distribution system infestations in which Copepoda and Rotifera are the dominant species.

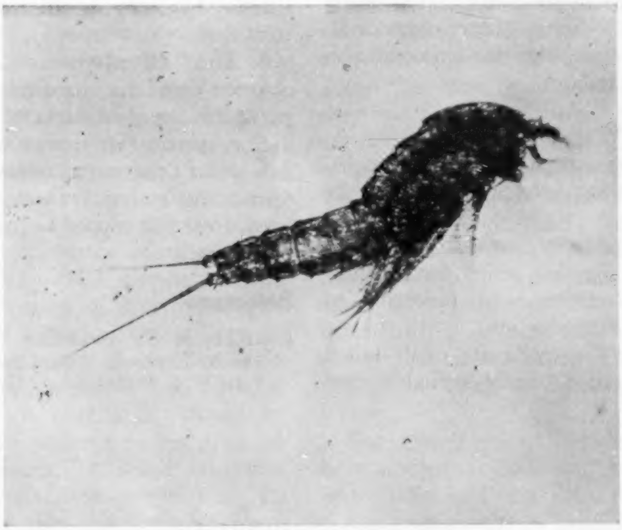

Fig. 2. Adult *Canthocamptus*

Both the adult Cyclops *and adult* Canthocamptus *are $\frac{1}{8}$–$\frac{3}{16}$ in. long, and can be identified by their characteristic swimming motion.*

The observation that copper-chlorine-ammonia is effective against worms was not specific for any worm other than the *Nais* worm. Others, recov-

ered from raw water and distribution system dead-end flushings, were killed but not identified. The water flea, which was frequently observed, was unquestionably killed, but the particular species of flea was not identified. It, too, carries and deposits eggs and these eggs have been observed and identified in filter effluents. At certain stages of development the water flea egg carries an embryo which is the exact image of the adult and is easily recognized. Some observations indicate that copper-chlorine-ammonia also kills Nematoda.

Conclusions

From the experience at Indianapolis, the following conclusions can be drawn:

1. Copepoda infestations are related to stored supplies which have conditions and environment favorable to Copepoda reproduction.

2. Adult Copepoda are easily killed by chlorination, with available free chlorine residuals of 1.0 ppm and sufficient time of contact.

3. Infestations in purified water result when many individual eggs pass the filters and hatch in the distribution system.

4. Copepoda growth in the distribution system can be eliminated by proper copper-chlorine-ammonia application.

5. Worms, water fleas, Rotifera, and possibly Nematoda can also be eliminated by copper-chlorine-ammonia treatment.

6. The effectiveness of copper-chlorine-ammonia treatment depends partly on the cleanliness of the distribution system. It cannot be as effective when dead ends contain chlorine-demanding material which, when utilized, frees the copper to precipitate as the carbonate.

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Bloodworms in Distribution Systems

J. K. G. Silvey

A paper presented on Jun. 13, 1955, at the Annual Conference, Chicago, Ill., by J. K. G. Silvey, Chairman, Div. of Science, North Texas State College, Denton, Tex.

THE occurrence of bloodworms, shown in Fig. 1, in water distribution systems has probably been commonplace since the time of the Roman aqueduct. One may actually anticipate the appearance of these immature midgeflies in any water supply that does not have ample means of flocculation, sedimentation, and filtration. It is interesting to observe that the bloodworms, as members of the family Chironomidae, exist throughout the temperate regions of North America. Most of the larvae of the midges are aquatic. We note that they live in decaying vegetable matter and in other areas of rich nutrition. If storage reservoirs or water supplies grow algae, protozoans, or small crustacea, one may anticipate ample food for their propogation and growth. Many of the species are blood red in color, and hence have been frequently known as bloodworms. To be sure, certain of the chironomids, or midges, produce larvae that are yellow or even clear in color. Some species are light tan and some are pink. In size, they vary from a few millimeters to slightly more than an inch.

Life History

In most of the members of the Chironomidae family, several stadia, or growth stages, are probable in the life-history. That is, when the bloodworms hatch from eggs that have been deposited in water, they are of small size. Then, if food conditions and other environmental factors are conducive to their continued existence, they will undergo ecdysis, or shedding of their old cover, resulting in differences in form and obvious growth. The bloodworms are active and are inclined in many instances to construct small tubes comprised of bits of dead leaves or particles of clay or sand which they fasten together with viscous threads. It is common to observe these tubes on the surface of stones or vegetation which is submerged in the water.

For many years, limnologists (*1*) have studied the bottom fauna of fresh-water lakes and reservoirs in order to procure specimens of the bloodworms that exist in that region. Because deep fresh-water lakes, as well as reservoirs, stratify during the summer season, it may be concluded that bloodworms are capable of living under anaerobic conditions. The mechanism by which the bloodworms are capable of normal activity in certain areas of fresh-water lakes has not been completely explained. This point, however, is important to the water works field, because distribution system contaminations may occur in waters that are low or devoid of oxygen. At the same time, numerous species of the chironomids may be observed simultaneously

existing in areas that have ample supplies of available dissolved oxygen.

Not only are the larvae of the chironomids active, but also the pupal stages may be motile. Many of the species increase in size and alter their morphology on going into pupation. Most of them finally approach the surface of the water in order for the adults to emerge. Individuals who visit the Adirondack Mountains or White Mountains in upper New York state are familiar with the sandflies, or punkies. These are minute species that frequently become very abundant and from time to time are unusually annoying because of their bites. Immature stages of these forms are also aquatic, although infrequently red.

From the above remarks, it can be presumed that the winged adults may be capable of depositing their eggs in many sections of a water system. Uncovered storage reservoirs of either raw or finished water become highly contaminated, particularly if there is a source of nutrition for the bloodworms. It is sufficient to point out that most uncovered reservoirs are inclined to be contaminated with algae. Sessile forms will afford a splendid environment for the bloodworms to complete their life-history. If large storage reservoirs are used, such as those found in certain parts of the East Coast as well as regions of the Far West, entrance of bloodworms from the reservoirs into the distribution system may be expected.

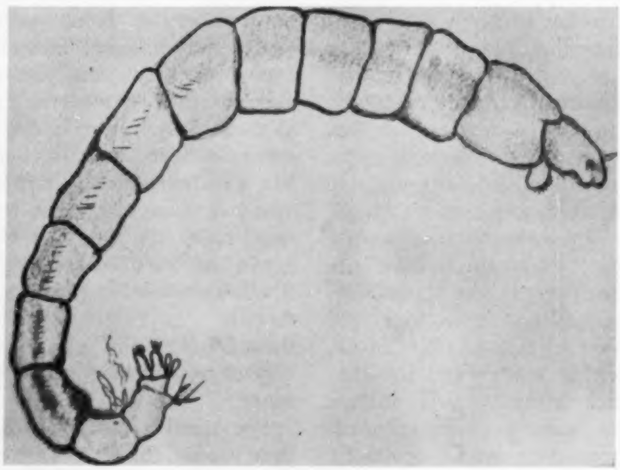

Fig. 1. Bloodworm

Bloodworms, or Chironomus *larva, exist throughout the temperate regions of North America. Their size varies from a few millimeters to slightly more than an inch in length.*

It is somewhat distressing for a housewife to open the tap and observe small bloodworms in a receptacle and, for that reason as well as many others, thorough investigations should be made relative to the control of these organisms. Flentje (*2*) has reviewed the

literature through 1945, showing the occurrence of bloodworms in a number of areas of America. Kelly (*3*) recently presented some very interesting material having to do with animal infestation in Norwich, England. The author of this article might add to the list of those troubled by infestations a few of the smaller water plants in the Southwest. These have elevated storage tanks that are uncovered and are subject to chironomid infestation from time to time, particularly in the spring and fall. Apparently the invasion of bloodworms into distribution systems is of sufficiently common occurrence to warrant thorough investigation.

Mechanical Methods of Control

Numerous techniques have been employed for the control of bloodworms in distribution systems. The most obvious method, if practical, would be to cover open reservoirs so that the female midgefly would not have access to the water supply for deposition of eggs. If the reservoirs are too large to be covered practically, some other method, such as the construction of rapid sand filters, may have to be used. Probably the best method employed to date is similar to the one accounted by Flentje (*2*) in western Pennsylvania. Rapid sand filters may, at times, be effective, although the construction and maintenance may offer considerable difficulty. Kelly (*3*) indicates that microstrainer cylinders having a 23-μ aperture are successful in the removal of *Nais* worms and other organisms in the Norwich, England water supply. Possibly, this mechanism might be investigated for use in the United States. Additional mechanical methods for the control of bloodworms have not been successfully employed so far as the writer is aware.

Biological Methods of Control

If the bloodworms are dependent on algae and certain microorganisms for food supply, the eradication of these algae and microorganisms by chemical means might result in final biological control. In a similar fashion, if the storage reservoir is earthen, rigid inspection should be carried out to effect reduction of emergent, floating, and submerged types of vegetation. Surber (*4–6*) has compiled accounts of experimental work in this field so that those interested in controlling the above types of vegetation may refer specifically to his work. Under normal conditions the algae may be controlled by the addition of various concentrations of copper. It might be suggested that in hard water, copper should be chelated so it will not precipitate as copper hydrate.

Numerous fish food studies have been published in the Middle West, particularly in Wisconsin and Michigan. Couey (*7*) and Leonard (*8*) completed some investigations which indicated the preference of many of the small sunfish for chironomid larvae. Fish culturists are aware that carp, goldfish, and various types of guppies prefer bloodworms to other types of diet. It would seem that the addition of some of these species of fish to storage reservoirs might enact proper control of chironomid larvae. It is important to note, however, that a delicate balance is necessary so that the fish will have ample diet and at the same time the chironomids will be largely consumed. It does not appear that additional biological methods have been investigated which can offer promise in control of invading bloodworms.

Chemical Methods of Control

Numerous attempts have been made to employ copper sulfate for the control of chironomid larvae. It is recalled that the respiratory mechanisms of the bloodworms are comprised of rather elaborate blood gills. In order for copper to be effective, it would be necessary that ample quantities of the metal pass into the respiratory apparatus, resulting in a poisoning effect. In all probability, the concentration of copper necessary to reduce the organisms would be relatively high.

There are numerous methods by which copper may be chelated for experimental tests. Copper has been employed both as copper citrate and copper ethylenediaminetetraacetate. The copper content is not stated as a complex but as parts per million of copper as copper. It is necessary, in testing the organisms, to make residual copper determinations from time to time to ascertain whether any of the metal is being lost. Five *Chironomus* larvae were placed in each experimental receptacle. The first receptacle received 2 ppm copper in a copper chelate form; the second, 4 ppm; the third, 8 ppm; and the fourth, 10 ppm. It appeared that the lethal concentration was 10 ppm after a period of 24 hr. Lower concentrations appeared to be ineffective.

TABLE 1

Lethal Concentrations of Organic Insecticides *

Insecticide	Concentration *ppm*
DDT	0.04
Chlordane	0.015
Lindane	0.006
Dieldrin	0.007
Aldrin	0.012
Sulfone	0.30
Tetraethylpyrophosphate	0.008
Parathion	0.008

* At least 50 per cent of the larvae were dead within 8 hr.

Chlorine dioxide, according to the literature, had not been investigated as a control for bloodworms. The gas generated was scrubbed out in deionized water and retained at a temperature of 18°C. Because it is difficult to maintain the gas in solution at warmer temperatures, constant tests must be made for residual chlorine dioxide. In experimental work described here, 1 ppm, 3 ppm, and 5 ppm were used. It was found that 5 ppm was a lethal concentration after a period of 24 hr. Lower concentrations did not appear to be lethal. Flentje (*2*) describes numerous experiments relative to the use of chlorine in the control of chironomid larvae. Since the results have been so variable, a series of experiments was set up using concentrations of 5 ppm and 7.5 ppm. Continuous residuals were run in order to be certain that the larvae were exposed to ample quantities of chlorine. It was noted that 7 ppm chlorine was lethal to the chironomid larvae in a 24-hr period. Lesser concentrations or reduced exposure time did not prove effective.

It is possible to produce a copper chelate of chloramine, and this material was tested against *Chironomus*. In the species tested it was found that the lethal concentration of copper-chlorine-ammonia was 4 ppm. The combined residual chlorine was 3 ppm. The time required to bleach and kill the chironomid larvae was approximately 24 hr. Because the common available practices currently used in water plants or in water reservoirs do not seem effective in normal concentrations, a number of organic insecticides were also tested. Flentje (*2*)

states that DDT in concentrations of 0.01 ppm was effective when employed in the Alexandria, Va., water supply in 1945. He also indicates that an insect powder containing pyrethrum was effective in concentrations of 3 ppm and that rotenone was effective as a lethal agent in small amounts, although he does not give the concentration. In the experimental series described here, the work on DDT was repeated and a number of insecticides that are either now on the market or in experimental use were added. The author does not suggest the use of these compounds in water supplies without special reference to authorities who are familiar with the toxicity of these compounds. Ingram and Tarzwell (*9*) have compiled a very useful bibliography of publications relating to the undesirable effects of insecticides, algicides, and weedicides upon aquatic life. The author suggests that reference be made to this publication and to other authorities before any of the organic insecticides be employed in a water supply that is to be used for human consumption.

Table 1 gives concentrations of insecticides required to kill 50 per cent of the larvae within a period of 8 hr.

Discussion

The occurrence of bloodworms in natural waters of the Middle West was investigated by Juday (*10*). Quantitative studies, which constituted some of the original research on these organisms in this country, were made by Birge and Juday (*11*) on Lake Mendota. The taxonomy of this group was worked out by Johansenn (*12*) in New York state in the early part of the 20th century. These forms have long been of importance to biologists because they have served as index organisms of biological fertility. Thienemann (*13*) recently completed a volume of *Die Binnengewasser* related exclusively to a consideration of *Chironomus*. In that volume he gives 48 pages of bibliography on the chironomids. Obviously, the investigation of this group of organisms throughout the world has been very extensive. Interestingly enough, however, few of the references mention water supply contamination. It would appear that the water works field has not sought information and aid from the fresh-water biologists commensurate with their requirements. The recent establishment of an AWWA task group for investigation of bloodworms and other organisms in distribution systems is obviously a step forward. The common methods of control normally applied in water purification plants will not serve as a control for *Chironomus* larvae nor apparently for the larvae of other aquatic insects. Organic insecticides appear to be indicated if the toxicity studies support the fact that they may be safely used in water supplies. This is another example of how problems in the water works field can be adequately solved with cooperative research. The proper operation of a complex water distribution system in modern society involves the services of multiple scientists in varied fields.

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Preventive Maintenance for Water Works

Panel Discussion

A panel discussion presented on Oct. 19, 1954, at the Southwest Section Meeting, El Paso, Texas.

Introduction—*John D. Wedeman*

A paper presented by John D. Wedeman, Chief of Water and Sewage, Engr. Sec., Headquarters 4th Army, Fort Sam Houston, Tex.

MAINTENANCE is the upkeep of property. Preventive maintenance is a type of maintenance which, with a minimum of major repairs, aims at consistent upkeep of property without interruption in service. It is accomplished on a regularly scheduled inspection tour and includes inspecting, servicing, recording, and reporting. Reporting consists of notifying supervisors of the need for repairs beyond the capacity of the individuals performing the preventive maintenance.

Probably the first slogan for preventive maintenance was "A Stitch in Time Saves Nine." Work, carefully planned and executed in an orderly manner, decreases the number of emergencies, increases efficiency, improves, service, and lowers the cost of both operation and maintenance. Inadequate planning or faulty execution of maintenance work will throw the work load out of balance and cause periods of intensive work alternating with periods of little or no work. Under these conditions, much of the jobs essential to a continuous and economical supply of water is deferred or is entirely neglected and a work load may develop which is insurmountable by the currently assigned personnel.

Figure 1 emphasizes the impact of the work load under haphazard "Breakdown Maintenance," as compared with proper planning and scheduling under "Preventive Maintenance." Under breakdown maintenance, the two general categories of workload are answering complaints and meeting emergencies. Prompt response to complaints is expensive and the complaints, because they are received at irregular intervals, create extremes of activity and inactivity resulting in sporadic work loads. Frequently occurring emergencies have an even more disastrous effect, because action on these cannot be postponed and may ultimately result in chaos. These necessitate increased material and personnel requirements. Major repair projects become necessary for continuation of the water supply. Costs of both operation and maintenance obviously increase, and the end result is dissatisfaction on the part of management, personnel, and the consumer.

Under preventive maintenance there are two categories of work load; scheduled maintenance and planned maintenance. Scheduled maintenance, because the work load is uniform, results in an absence of confusion and a mini-

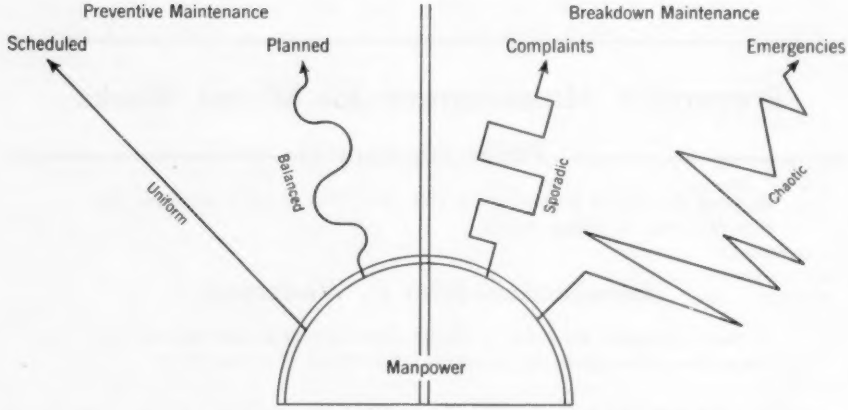


Fig. 1. Effects of Breakdown and Preventive Maintenance

Preventive maintenance, because the work load is uniform and scheduled for lulls in normal operation, results in an absence of confusion and a minimum of lost motion. Breakdown maintenance, because it is based on prompt response to complaints, results in extremes of activity and inactivity.

mum of lost motion. Planned maintenance results in performing the work load during lulls in normal operation.

Even planned maintenance varies in weight, of course, but there need be no confusion and only very little lost motion, and the end result is a balanced work load. Personnel and material requirements decrease and the need for major repair projects is held to a minimum. The cost of water declines, management and consumer are satisfied, and the morale of operating personnel is high.

Under the very best operation, there will be some of both types of maintenance, but, with a sound and efficient preventive-maintenance program, the larger portion of the work load will be accomplished in the most economical manner and with the most satisfactory result.

US Army Program—*John D. Wedeman*

A paper presented by John D. Wedeman, Chief of Water and Sewage, Engr. Sec., Headquarters 4th Army, Fort Sam Houston, Tex.

In 1939, all US Army personnel stationed in this country were housed in 180 army posts. By 1945, to meet the requirements of World War II, the number of posts was increased to 435, and the water supply facilities at these posts represented an investment of many millions of dollars. The degree of maintenance of these facilities prior to World War II, although not poor, was lacking in uniformity and positive action. It was probably equal, however, to that of the average municipality of that time. The rapid expansion of facilities and the employment of personnel who were unfamiliar with the

new installations or, in some cases, with any water works systems at all, emphasized the need for a uniform and positive program. To supply this need, the chief of engineers called together a group of outstanding water works engineers, operators, and equipment manufacturers. These men gave freely and diligently of their time, collaborating in the development of a modern, simple, and effective preventive-maintenance program. The procedures these men developed were tried and tested in the field under actual operating conditions, modified according to the findings, compiled in a technical manual, and introduced to the post engineer organizations at all army installations.

Cataloging

In any preventive-maintenance program there are two major functions: the scheduling of activities and the execution and recording of the finished activities.

In the Department of the Army preventive-maintenance program for water works, the first step toward scheduling activities was to catalog the equipment. An equipment classification code using alphabetical and numerical designations was convenient and simple. The code uses a letter to identify the particular utility, a digit designates the class of equipment, and a decimal differentiates between the types of equipment in each class. Thus, classification for prime movers and wells would be as follows:

W1.0—*Prime Movers.*
  W1.1—Electric Motors.
  W1.2—Gasoline Engines.
W2.0—*Wells.*
  W2.1—Straight-bored.
  W2.2—Large Gravel-Wall.

The next step was to identify, by number, each piece of installed equipment. A hyphenated system was generally used. By this system, the first group of numbers is that of the building or functional structure in which the equipment is located. The equipment classification code number, as described above, is selected, and the number distinguishing the individual piece of equipment from other identical units in the same building is assigned. For example, No. T-431-W1.1-4 indicates that in Building No. T-431, in the water supply system (W) there is a prime mover (1) consisting of an electric motor (.1) which is one of four or more motors (4).

Record Cards

Figure 2 shows the card used in recording inspection and service information, and Fig. 3 shows examples of the data which the finished cards contain.

The form entitled "Utilities Inspection and Service Record" provides the means of preparing in written form the appropriate inspection or service required by each piece of equipment or structure. Another form on the reverse of the card, shown at the bottom of Fig. 2, provides a means of recording each service or inspection performed, the initials of the worker, and the date the service or inspection was completed. The third step is to transcribe the equipment number and description from the previously prepared catalog to the appropriate spaces on the card as shown in Fig. 3.

On the left-hand side of the pages of the catalog, or manual, opposite the paragraph pertaining to each particular piece of equipment, are the item numbers corresponding to each operation in the inspection and service procedure of the unit, as shown in Fig. 4. The

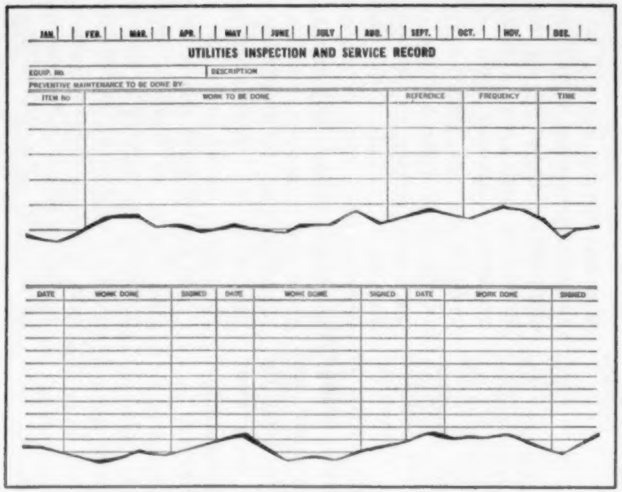


Fig. 2. Inspection and Service Record Form

One side of the card provides space for recording the inspection or service required by each piece of equipment or structure. The reverse side, shown at the bottom of the figure, is for recording the date the service or inspection is performed and the initials of the worker responsible.

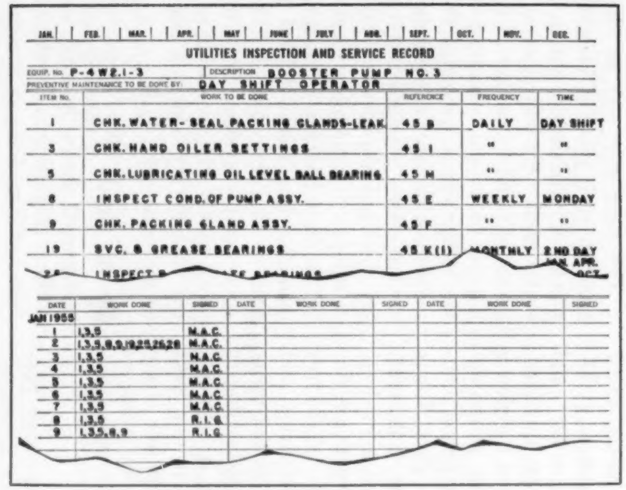
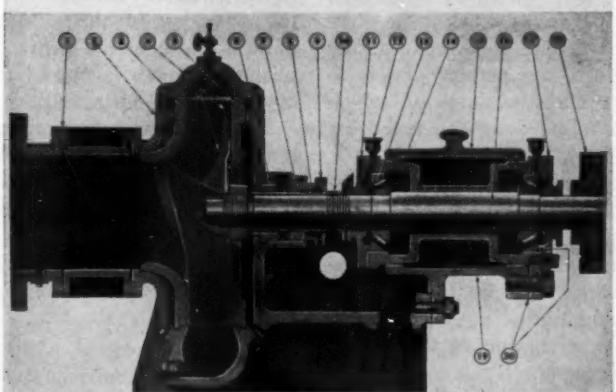


Fig. 3. Completed Record Form

Information on the front of the completed card gives a brief description of the operation to be performed, key letters to relate the operation to the manual, and an item number to identify the equipment in the manual. The reverse side of the completed card shows when and by whom the work was performed.



DAILY	WEEKLY	MONTHLY	QUARTERLY	SEMIANNUALLY	ANNUALLY	
						hand. If serious leakage continues, renew packing, shaft, or shaft sleeve. (See also *a* (2) above.)
2						*c.* **Check Grease-sealed Packing Glands.** If grease is used in packing gland as a water seal, maintain constant grease pressure on packing during operation. When a spring-loaded grease cup is used, keep it loaded with WP grease. Check to see that grease is being forced through packing at rate of about 1 ounce per day.
	7					*d.* **Alternate Operation of Two or More Pumps.** If two or more pumps of the same size are present, alternate them to equalize wear, keep motor windings dry, and distribute lubricant properly.
	8					*e.* **Inspect Condition of Pump Assembly.** (1) Check float controls to make sure they respond to rising water level in clear well. Use light oil on mechanical

Figure 41. Open-impeller centrifugal pump.

Fig. 4. Page From Technical Manual

The manual was prepared from work done by a group of outstanding water works engineers. Along with illustrations of equipment and numbers to identify the various parts, the manual contains detailed descriptions of each inspection or service operation.

item numbers are located under column headings which indicate the frequency of action, such as daily, weekly, and monthly. An asterisk in the column indicates a varying maintenance frequency which has not yet been definitely established, awaiting additional data.

The fourth step consists of transcribing the data from the manual to the front side of the card. These data include: [1] a brief description of the required inspection or service; [2] the identity by paragraph and subparagraph of the detailed instructions for the inspection and service as set forth

in the manual; [3] the frequency; and [4] the item number as prescribed by the manual. This is shown on the completed card in Fig. 3. These data, if not already available from the manual, are obtained from equipment manufacturers and from operating experience, and are set up as an appendix to the manual.

When all of the cards covering work of a similar nature or work to be done by a certain group are prepared, the name or title of the person who is to do the work and the dates on which the work is to be done are noted, as shown in Fig. 4.

Scheduling activities and establishing the record card system needs to be done only once.

Execution and recording of preventive maintenance, however, are periodically recurring duties. As previously stated, the reverse side of the record card provides space for recording the completion of scheduled inspections and services. The card at the bottom of Fig. 3 has this information recorded. The date on which the inspections or services were performed, the item numbers of the inspections or services, notations as to abnormal conditions found, and the initials of the employee are written in by the worker performing the job.

When the inspection report indicates the need of services beyond the capacity of the personnel performing the preventive maintenance, the supervisor reviewing the cards issues a work order for accomplishment by appropriate personnel. Tabs may be placed on the top edge of the card for work requiring attention in the next succeeding month. When the work is accomplished, the tab is moved to the next month marked for attention.

The importance of preventive maintenance is obviously greater than the recording of the work involved. As the record card is also the schedule of performance, however, the recording of the work done is an incidental act which takes only a moment and is extremely helpful.

Conclusion

A preventive-maintenance program is effective only when careful, accurate, and complete records are kept of all work done. There is no other way in which an operator can be certain he has performed his duties or a supervisor can be sure he has executed his responsibilities.

Maintenance Design—*Benjamin B. Ewing*

A paper presented by Benjamin B. Ewing, Asst. Prof., Dept. of Civ. Eng., University of Texas, Austin, Tex.

In the water works industry, one often hears the remark, "If the engineer who designed this plant had to operate it, he would surely have designed it differently." Certainly there is some justification for the statement, and it is this problem of design that will be discussed here. The design of a water works system is only one phase of the whole problem, however. Equally important are construction, operation, and maintenance.

If the design engineer is familiar with all phases of the problem, there are many features which can be incorporated in the design that will result in an overall minimum cost for construction, maintenance, and operation.

It is sometimes difficult for the design engineer to incorporate these features in his plans and specifications, partly because it is difficult to convince clients that increasing initial cost results in lower yearly maintenance and operating costs, and partly because it is difficult for the designer to anticipate the maintenance and operating problems of the user of the plant. There are certain general statements, however, which may serve to clarify the situation, and they will be discussed as they pertain to distribution systems, pumping stations, and treatment plants.

Distribution Systems

Much of the maintenance of water distribution systems is required by the valves, fire hydrants, and the elevated steel tanks. The design engineer should keep in mind, however, that it will occasionally be necessary to make both routine and emergency repairs to pipe systems. He should therefore include in his design an adequate number of valves for effective shutdowns when required. The liberal use of gate valves in the distribution system will simplify the problems of maintenance men. Cast-iron pipe may be encased in a sand blanket in the trench if nonuniform soil characteristics indicate external corrosion is likely. The design engineer should also consider the construction features of fire hydrants in preparing specifications to insure that they will require minimum maintenance. The location of fire hydrants in the distribution system should be studied to get the most effective use and still place the hydrants in the safest spots possible.

The type of distribution system reservoirs selected in the design of a water works system is usually governed by the hydraulics of the system, the terrain of the land, and the initial cost of the tank. Where there is any choice, however, ground storage reservoirs are much preferred to elevated tanks by the water works superintendent who must maintain them. If steel tanks are used, the design engineer should carefully consider the corrosion possibilities and, if desirable, incorporate a cathodic protection system in his design to eliminate frequent painting. Concrete tanks are highly desirable because of the low maintenance requirement.

Pumping Stations

The term "pumping stations," as used here, is a broad one. It includes those pumping stations which are an integral part of the treatment plant. It also includes isolated booster stations in the distribution system, well field central pumping stations, and individual well pumps. The maintenance aspects of all are similar.

One of the most important features of an effective preventive maintenance program is good housekeeping, and much can be done in the design of a pumping station to simplify housekeeping procedures. It has been said that the dark kitchen is a dirty kitchen, and the same applies to pumping stations. It seems only reasonable that if the dirt cannot be seen, it cannot be removed. It is important, therefore, that the design of the pumping station should provide a light, well ventilated room with no dark corners and no areas of shadow. It is also desirable that bright, cheerful color schemes be incorporated in the interior finish. Light colors on ceilings and high walls will make for more effective lighting, but the same light colors should be avoided on the lower walls and floors because of the difficulties in keeping

them clean. Many pumping stations are partly below ground. In areas with a high ground water table or where surface water percolation is encountered, walls and floors of pumping stations should be waterproofed to prevent sweating or condensation. All pumping stations should be provided with adequate floor drains and drains in sumps. The floor slope toward these drains should be at enough of an incline so that the floor can be easily hosed down.

It is important that adequate working space be provided in pumping stations to allow the maintenance men to get around machinery with a minimum of difficulty. The floor space should not be skimped in the original design, particularly if there are possibilities that pumping stations will be altered at later dates to provide additional or larger-capacity pumps. It is desirable that there be an uncomplicated piping arrangement in pumping stations to provide clearance for disassembling equipment and to provide a passageway for the operating and maintenance personnel. The piping arrangement is often simplified by placing the pipes in sumps rather than on the floor or above the floor. This makes for greater ease in getting around the station.

Every pumping station should have some provision for a crane to be used in handling heavy materials or equipment for maintenance purposes. On indoor installations, if the pumping station is of a permanent nature, this should be a permanent overhead crane. For temporary construction it may be possible to depend upon an A-frame or a portable derrick, and consideration must then be given in the design of the structure for overhead clearance. One pumping station in central Texas is located in a temporary wood-frame building and a permanent crane was not justified, but the ceiling is too low to permit use of an A-frame.

For well pumps, a permanent derrick may be constructed over each well pump house. Sometimes, in a well field, only one derrick is constructed, but it is built in such a manner that it can be erected over any of the well houses. A mobile crane may also be used for maintenance of a well pump, but provision should then be made for easy removal of the well house roof. The well houses at Fort Bliss, Texas, have been designed in such a way that not only a large part of the roof section can be removed, but also all of the front wall over the doorway. This has proved to be a particularly desirable feature for maintenance work, because a mobile crane can move heavy equipment out through the doorway without difficulty.

Every pumping station should be provided with a tool room or a tool rack and work bench with adequate space for maintenance work. On large treatment plants with widely separated high-lift and low-lift pumping stations, it is desirable that each pump room have its own tool rack and shop space. It is also desirable that electric power outlets be located at those places which will permit ready use of electric machine tools on pumps, motors, valves, and control equipment. These outlets should be located at frequent intervals about the pumping room and particularly close to those areas where machine tools are likely to be used. In the design and construction of its new water treatment plant, Austin, Tex., has incorporated numerous compressed-air connections for the use of pneumatic tools.

Much of the maintenance cost of a water-pumping station is not devoted to the pumps, motors, pipes, and control mechanisms, but goes, rather, to maintaining the structure which houses these facilities. There is much that the design engineer can do to reduce these costs by selecting a permanent material for wall, floor, and roof construction, rather than materials which require frequent painting. The use of aluminum window frames is also advisable. There seems to have been a trend in recent years to reduce building costs by using vertical turbine-type pumps with weatherproof motors, which need not be housed in a fireproof building. This reduces both the initial cost and maintenance costs. Such construction is not restricted to well pumps, however, and can be used for booster pumping stations and high-service pumping stations. Another recent development in the water works industry has been the submersible-motor pump. This not only eliminates the pumping-station building, but eliminates all surface equipment, the pump and motor both being located underground.

The frequency and degree of maintenance required for the pumps can best be determined by making periodic tests of the pump efficiency to determine performance. Such tests require measurement of the electric and hydraulic factors involved. Facilities for making these measurements, including pressure gages on both the suction and discharge side of every pump, a flowmeter for measuring discharge, and an electric meter for measuring power consumption, should be included in the design of the pumping station. The performance of a well is determined by measurement of the water level at periodic intervals. For this purpose, air lines should therefore be installed in all wells.

Treatment Plants

Many of the remarks pertaining to design aspects of pumping-plant maintenance apply equally well to the design of treatment plants. Housekeeping is an important problem of treatment plants, and work areas should therefore be designed for easy, economical, and convenient cleaning. Chlorination equipment should be located in a separate room to prevent the corrosive gas from coming in contact with other equipment. Again, it is important that adequate working space be provided around machinery which will require preventive maintenance and it is important that this equipment be arranged in such a way as to facilitate access. The consideration of accessibility must be kept in mind in locating such items as motors, gear boxes, chlorinators and other chemical feeders, operating tables, and rate controllers. Alemite fittings should be readily accessible, and adequate space should be provided in the original design for future installation of additional equipment. Progress in the water works industry has continually led to the use of more control equipment. New treatment processes frequently require additional equipment. Filter plants should have a pipe gallery with adequate space and with a piping arrangement which facilitates access to such pieces of equipment as rate controllers, hydraulic valves, and operating table mechanisms.

All water treatment plants have a certain amount of equipment which is inaccessible for routine maintenance. This equipment includes sludge scrap-

ers and other sludge removal mechanisms, underwater flocculator equipment, and such semi-inaccessible equipment as chemical conveyor. Deep-well equipment is also in this category. The maintenance problem here is even more important than for items which can be readily inspected and serviced, and the design engineer should give particular consideration to the selection of such inaccessible equipment.

He should consider among other things the number of moving parts involved. The cost of maintenance of a water treatment plant is just about directly proportional to the amount of mechanical equipment. Even though initial cost may be higher and flexibility of operation may be impaired, the design engineer may want to give serious consideration to over-and-under baffles, hydraulic jumps, and other mixing and flocculating devices which are free of mechanical devices and their high maintenance costs. Even with mechanical equipment, he may wish to consider the speed of operation, because high-speed motion requires more maintenance than slow-speed operation.

The engineer should consider very carefully the design of mechanical equipment which is completely inaccessible for maintenance and service once it is installed. He should check it for jamming in case of wear of parts or obstruction by a foreign object. He should check its lubrication system and consider the use of sealed-in mechanisms which require no lubricating. He should watch for the danger of abrasive action, if there is a material in the water or sludge which would be of a gritty nature. He should be particularly concerned about the possibility of corrosion of a mechanism. Corrosion seems to be a particular problem on those parts which are partly submerged and partly subjected to the air, such as the drive chains on chain sludge collectors. The flight chains which are continuously submerged have been found in many cases to be less susceptible to corrosion than the drive chains. Often shafts and other parts of rotating equipment are found to be subject to greater corrosion in the sections which are alternately wet and dry. If corrosion seems likely, wood, asbestos-cement, concrete, or corrosion-resistant alloys may replace steel, or protective coatings may be applied.

Anticipated Lack of Maintenance

There is no such thing as a water works system which requires no maintenance, but an engineer is occasionally faced with a conviction that the plant he is about to design will receive very little maintenance, particularly of the preventive type. In this case, he should consider the elimination of all possible mechanisms. This may be done by using baffled tanks or hydraulic jumps for mixing and by using hopper bottom clarifiers for gravity sludge removal. Surfaces which require frequent painting can be avoided. All the maintenance-saving features of design which have been discussed should be given greater attention when the future plant is to receive a minimum of maintenance.

Conclusion

It has been pointed out that many of the maintenance-saving features discussed require no additional construction cost. Others require slightly

higher initial costs but result in large annual savings in maintenance cost. It is the responsibility of the design engineer to include these features in order to provide a plant that will result in lowest overall cost to his client. The maintenance superintendent, if he has an opportunity to review the plans and specifications, should be certain that these features are incorporated in the design.

The ideas presented here are not new revelations to the water works industry, but it is hoped that they will serve as a check list and thus help designers and the maintenance men to recall some of the things that have possibly been forgotten.

Program at Little Rock, Ark.—*Jack H. Wilson*

A paper presented by Jack H. Wilson, Engr., Munic. Water Works, Little Rock, Ark.

Little Rock Program

There is no organized program of preventive maintenance, as such, in the Little Rock, Ark., plant, but each item requiring attention is the responsibility of a particular individual. It is felt that the only method by which inspection and other requirements will be attended to is to make them the responsibility of some one person. The basis for this program is expressed in the adage, "what is everybody's business is nobody's business."

Source of Supply

Beginning with the Little Rock, Ark., source of supply, which is a dam on the Alum Fork of the Saline River in the Ouachita National Forest, there are several items which require attention peculiar to themselves alone. The dam requires mowing to prevent the growth of trees in the earth of the embankment. Periodic inspection must be made and any displaced riprap must be restored. Monthly measurements are made of the flow over a V-notch weir of water leaking through one abutment to make certain that leakage hasn't increased. The spillway must be examined and joints must be resealed where sealing material has been washed.

The bridge over the spillway must occasionally be cleaned and repainted, particular attention being given to those points in the connections that are difficult to reach and in which water will collect and cause corrosion.

The drainage ditches on the berms must be inspected annually and cleaned, and bridges over these drains must be inspected for possible repairs.

The watershed itself requires annual inspection. To prevent erosion and keep down the turbidity in the lake, it is necessary to place dead trees or rock in places where washes may develop. Every few years it is necessary to go over, clear, and mark the property lines.

Main Supply Line

The main supply line has to be examined periodically, and those places where mountain streams threaten to wash underneath the pipeline may require filling with rock or reinforced concrete. Occasionally it has been necessary to divert some creeks to protect the pipeline.

All blowoff valves must be examined annually and necessary repacking must

be done. Each winter, to prevent freezing, the air valves are closed off and drained until the following spring.

Although most of right-of-way for the pipeline is the property of the municipal water works, use of the land by adjacent owners is encouraged and gates are installed so that they may fence across the line. This tends to prevent the use of the utility's maintenance road by the people engaged in logging operations and thus avoids possible tampering with the aboveground structures. During dry periods it is necessary to weld shut the manhole lids in certain locations to prevent unauthorized removal of water from the pipeline. Besides the loss of water, persons causing this unauthorized removal of water sometimes damage air release and blowoff valves.

Treatment Plant

At the treatment plant, attention is required by many basins with reinforced-concrete roofs to prevent material from lodging in the expansion joints and causing damage to the concrete. The buildings themselves require annual inspection, and metal and other surfaces that have deteriorated since previous inspection need periodic cleaning and repainting. On some of the older buildings it is necessary to point up some of the joints in the brick masonry to maintain its resistance to the elements.

Periodic inspection of roofs should be made so that any damage or deterioration can be repaired. This will be helpful in preventing damage to the interior of the building.

Various items of equipment require special attention and it has been the practice at Little Rock to follow the manufacturers' recommendations as closely as possible.

It is necessary to keep chlorinators and ammoniators in the driest places available. Such places must be well ventilated to remove any escaping chlorine, and the equipment must be well greased to protect against corrosion. It is advisable to check frequently and immediately stop any leaks that may develop. All other instruments and equipment should be inspected and kept dry, oiled, and adjusted.

Dry chemical-feeding machines must occasionally be torn down, cleaned, and inspected, and the worn parts should be replaced.

An experienced repair man makes annual inspections of all electrical equipment and motors to check for resistance, balanced loads, and voltage. Motors and pumps must be cleaned and oiled. Inspection of electrical equipment should be made only by skilled workmen. Standby pumps should be operated at regular intervals to assure that they will be in operating condition when required.

Control valves and piping, because they are of cast iron, do not require too much attention, but the bolts that hold the flanges together are a constant problem in the pipe gallery because of high humidity. It is necessary, occasionally, to replace the leathers in the hydraulic valves in order to insure positive operation.

Distribution System

In the distribution system, only those facilities which are above ground lend themselves readily to preventive maintenance. Probably the most prominent of these is the elevated tank or standpipe. In the Little Rock plant there are four of these and the policy is to

inspect the interior of these tanks annually. In cases where consideration might be given to cleaning and painting or repair, advice of the State Boiler Inspector's office is used as the authority.

The next most important parts of the distribution system are the fire hydrants. The practice in Little Rock is for each hydrant to be inspected at least once each year, and those hydrants in the high-value district are checked more frequently, particularly during icy weather. The man making this inspection checks the nipples, caps, condition of the hydrant, and whether or not the hydrant drains. He has found several hydrants in which the barrel was broken but no water was leaking, and there was very little evidence to indicate the hydrant had been hit. Approximately every 6 years each hydrant is tested and given a new coat of paint.

It is not the practice in Little Rock to make periodic inspection of valves of 12 in. or less in size. The larger valves are checked every year or two to be sure that they can be easily operated. If there is any indication at that time that maintenance is needed, these valves are dug up and such difficulties are corrected.

Any meters that are not checked for some other reason should be replaced in 7–10 years and tested. If any are shown then to be inaccurate, they can be broken down and repaired before being placed back in service.

The construction department tries to follow the manufacturers' recommended lubrication schedule on the heavy equipment. In addition, it periodically sends the equipment back to the company from which it was bought for cleaning, adjusting, and repair. This practice tends to correct malfunctions before they become of serious consequence.

Large tapping machines are periodically cleaned and oiled and the small machines used in running services are cleaned before each tap.

Vehicles

Probably the most thorough system of preventive maintenance at Little Rock is that used on wheeled vehicles. This maintenance is handled by a commercial garage and the practice is to have vehicles lubricated very 1,000 miles or at least once each month. The garage keeps a record on what is done to each unit and notifies the plant if one is over-due for any kind of lubrication or maintenance. When the cars are lubricated, they also receive a safety check for lights, brakes, and steering mechanism. Such items as air in the tires, water in the battery and radiator, and gas are the drivers' responsibility. These points are checked when the vehicles are lubricated at the garage and the management is notified if there is evidence that the driver has been negligent.

Other Items

In the general office, all office machines are under a manufacturers' maintenance contract. Under this contract, the manufacturer makes periodic inspections, and also cleans and adjusts the machines at the same time. This includes service on eleven typewriters, twelve adding machines, three calculators, one mailing machine, one mail opener, three billing machines, and one addressograph machine.

Fire extinguishers are checked annually and, if necessary, are drained

and refilled. Carbon dioxide extinguishers are checked by weight.

To enable management to keep employees on jobs within their physical capacities and to insure that physical disabilities that develop during the year do not go unnoticed, each employee is given a physical examination annually.

The two-way radio communication system is leased from the Southwestern Bell Telephone Company, and it is the company's practice to make periodic checks even though no maintenance is required at that time. This practice uncovers some weaknesses and gives better service.

The elevator used for handling dry chemicals is checked every few years for safety by a competent elevator man. A sign is kept posted showing the allowable load to be used on this piece of equipment.

Electrical wiring, steel cables, pulleys, and tools require normal inspection to determine the extent of wear that has developed. Such adjustments, maintenance, or replacement as is suitable in the particular case is made.

To insure that change in personnel or job responsibility does not permit some item to be overlooked, a check sheet or report should be made.

It is important that maintenance manuals, drawings, operation instructions, and service records be maintained for each item of equipment.

Inspection of electrical equipment should be made only by skilled workmen.

Conclusion

It is important to recognize the value of preventive maintenance for economical and efficient operation. It is important in good housekeeping and for safety, and management should continually show an interest in this phase of the water works operation.

Permanganate-Azide Test for Total Chromium in Water

Maxim Lieber

A contribution to the Journal by Maxim Lieber, Assoc. San. Chemist, Div. of Labs. and Research, Nassau County Dept. of Health, Hempstead, N.Y.

THE diphenylcarbazide procedure for the analysis of hexavalent chromium in water is reliable and accurate. This method depends upon the color reaction between hexavalent chromium and a diphenylcarbazide reagent, resulting in a characteristic reddish-violet color, following Beer's Law. This reaction does not occur with trivalent or bivalent chromium. To facilitate the determination of the total chromium which may be present in a water, it has been found feasible to oxidize the polyvalent chromium ions to the hexavalent state. Once this has been accomplished, the chromium is measured colorimetrically or photometrically by utilizing the diphenylcarbazide color reaction.

The original standard method for total chromium (*1*) utilized perchloric acid for the oxidation operation. The shortcomings of this procedure were evidenced by its lack of precision. It was also a difficult method to use on waters containing significant quantities of organic material. In the attempt to find a more reliable test for total chromium, comparative studies of new procedures were conducted by the Nassau County Division of Laboratories and Research, Hempstead, N.Y., the US Public Health Service, and the New York State Health Department Laboratories (*2*). The results of these studies led to the inclusion of the alkaline bromate and the permanganate oxidation procedures in the current issue of *Standard Methods* (*3*). The Nassau County Division of Laboratories and Research has found the latter procedure the more desirable. It circumvents the undesirable effect of organic or reducing materials which may be present in the water under examination.

Standard Method

According to the presently accepted procedure for total chromium, *Standard Methods* advises the use of the diphenylcarbazide reagent for the final hexavalent chromium color reaction after the permanganate oxidation. It also specifies that the final color reaction be compared with standards, or by photometric means, "at least 5, but not later than 20 min, after the reagent is added."

It has been noted that, when a total chromium analysis is done according to the *Standard Methods* permanganate oxidation procedure, the final color reaction at the end of 5 min is significantly less than at the end of 15 min. This is evident when the amount of sample used for analysis contains more than 0.005 mg of chromium. To observe this more carefully, a series of hexavalent chromium standards were prepared in duplicate. For each analysis, 50-ml portions of the prepared

TABLE 1
Results of Tests With Permanganate Oxidation Method

Test Used*	Hexavalent Chromium (Cr^{6+}) Present—*mg/l*				
	Prepared Standard	After 5 min	After 10 min	After 15 min	After 20 min
H	0.00	<0.005	<0.005	<0.005	<0.005
SM	0.00	<0.005	<0.005	<0.005	<0.005
H	0.02	0.02	0.02	0.02	0.02
SM	0.02	0.02	0.02	0.02	0.02
H	0.04	0.04	0.04	0.04	0.04
SM	0.04	0.035	0.04	0.035	0.035
H	0.06	0.06	0.06	0.06	0.06
SM	0.06	0.05	0.05	0105	0.05
H	0.08	0.085	0.085	0.085	0.085
SM	0.08	0.07	0.075	0.075	0.075
H	0.10	0.10	0.10	0.10	0.10
SM	0.10	0.08	0.095	0.095	0.095
H	0.12	0.12	0.12	0.12	0.12
SM	0.12	0.10	0.115	0.115	0.11
H	0.14	0.14	0.14	0.14	0.14
SM	0.14	0.105	0.13	0.13	0.13
H	0.16	0.16	0.16	0.16	0.16
SM	0.16	0.14	0.15	0.155	0.155
H	0.18	0.185	0.185	0.185	0.18
SM	0.18	0.135	0.165	0.165	0.165
H	0.20	0.205	0.205	0.20	0.20
SM	0.20	0.145	0.17	0.17	0.175
H	0.22	0.22	0.22	0.22	0.22
SM	0.22	0.17	0.205	0.21	0.21
H	0.24	0.24	0.24	0.24	0.24
SM	0.24	0.19	0.22	0.225	0.225
H	0.26	0.26	0.26	0.26	0.26
SM	0.26	0.20	0.225	0.23	0.23
H	0.28	0.275	0.275	0.275	0.27
SM	0.28	0.235	0.26	0.265	0.26
H	0.30	0.30	0.30	0.30	0.30
SM	0.30	0.24	0.28	0.28	0.28
H	0.32	0.31	0.31	0.31	0.31
SM	0.32	0.26	0.295	0.295	0.29
H	0.34	0.34	0.34	0.34	0.34
SM	0.34	0.27	0.31	0.31	0.305
H	0.36	0.36	0.36	0.36	0.36
SM	0.36	0.28	0.325	0.33	0.33

* H stands for direct hexavalent chromium test; SM for hexavalent chromium test after completing *Standard Methods* permanganate oxidation for total chromium.

standards were used. To one set of standards the accepted hexavalent chromium test was completed using the diphenylcarbazide reagent. The colorimetric readings were made with a photometer nulled against distilled water at filter No. 520. Readings were made at 5-min intervals up to and including 20 min. The duplicate set of standards was subjected to the permanganate oxidation method specified in *Standard Methods.* The final color reaction with diphenylcarbazide was again compared with the photometer at 5-min intervals up to and including 20 min. Table 1 is a consolidation of the observed data.

It can be seen that in all instances, the standard procedure for hexavalent chromium analysis is valid whether the color comparison is made after 5 min, or up to 20 min. That is in full compliance with *Standard Methods.* However, once the permanganate oxidation method is employed, the final hexavalent chromium color reaction proceeds more slowly with the diphenylcarbazide reagent. The optimum color density appears to develop at the end of 15 min. Therefore the latitude in comparison time as specified in *Standard Methods* does not apply in the permanganate oxidation for total chromium. The 15-min interval seems to be the desirable contact period between the oxidized chromium ions and the diphenylcarbazide reagent. This permits a more complete retrieval of the metallic ion under examination, resulting in a greater accuracy and precision of analytical values.

Permanganate-Azide Method

The observed discrepancy in the present *Standard Methods* procedure for total chromium by the permanganate oxidation was overcome and

improved upon in this laboratory. That was accomplished by utilizing sodium azide as the reducing agent (*4*). The azide reagent eliminates the excess permanganate after the chromium oxidation has been completed. The procedure for this permanganate-azide method is as follows:

Reagents

1. Sulfuric acid (1 + 1)
2. Diphenylcarbazide reagent, prepared as directed in Method A, Sec. 3.1 (*3*)
3. Sodium sulfite solution (1.26 g Na_2SO_3 in distilled water and diluted to 100 ml)
4. Potassium permanganate solution (0.632 g of $KMnO_4$ in distilled water and diluted to 100 ml)
5. Sodium azide solution (5-per cent solution of NaN_3 in distilled water). This solution is stable for at least 2 months.

Procedure

To the sample in an Erlenmeyer flask add 5 ml of H_2SO_4 and 1 ml of sulfite reagent. Allow to stand 10 min for complete reduction of any hexavalent chromium that may be in the sample. Add two glass beads and cover flask with a small funnel, which acts as an improvised reflux condenser. Evaporate to fumes and, if necessary, continue fuming operation to clear sample. Cool and dilute with distilled water to approximately 50 ml. Bring to a boil and add $KMnO_4$ solution dropwise until a faint pink color appears, then add several drops in excess. Boil for approximately 10 min. Add NaN_3 reagent dropwise and continue boiling until all the excess permanganate has been reduced and the solution becomes colorless. Cool sample, transfer to a 50-ml Nessler tube, and bring up to

TABLE 2

Results of Tests With Permanganate-Azide Oxidation Method

Test Used*	Amount of Hexavalent Chromium (Cr^{6+}) Present—*mg/l*				
	Prepared Standard	After 5 min	After 10 min	After 15 min	After 20 min
H	0.00	<0.005	<0.005	<0.005	<0.005
PA	0.00	<0.005	<0.005	<0.005	<0.005
H	0.02	0.02	0.02	0.02	0.02
PA	0.02	0.015	0.01	0.01	0.01
H	0.04	0.04	0.04	0.04	0.04
PA	0.04	0.035	0.035	0.03	0.03
H	0.06	0.06	0.06	0.06	0.06
PA	0.06	0.05	0.05	0.05	0.05
H	0.08	0.085	0.085	0.085	0.085
PA	0.08	0.065	0.065	0.06	0.055
H	0.10	0.10	0.10	0.10	0.10
PA	0.10	0.09	0.09	0.09	0.085
H	0.12	0.12	0.12	0.12	0.12
PA	0.12	0.10	0.10	0.095	0.095
H	0.14	0.14	0.14	0.14	0.14
PA	0.14	0.125	0.125	0.12	0.12
H	0.16	0.16	0.16	0.16	0.16
PA	0.16	0.145	0.14	0.14	0.135
H	0.18	0.185	0.185	0.185	0.18
PA	0.18	0.165	0.165	0.16	0.16
H	0.20	0.205	0.205	0.20	0.20
PA	0.20	0.185	0.185	0.18	0.175
H	0.22	0.22	0.22	0.22	0.22
PA	0.22	0.205	0.20	0.195	0.19
H	0.24	0.24	0.24	0.24	0.24
PA	0.24	0.22	0.22	0.215	0.21
H	0.26	0.26	0.26	0.26	0.26
PA	0.26	0.225	0.215	0.21	0.205
H	0.28	0.275	0.275	0.27	0.27
PA	0.28	0.245	0.24	0.23	0.23
H	0.30	0.30	0.30	0.30	0.30
PA	0.30	0.27	0.27	0.26	0.255
H	0.32	0.31	0.31	0.31	0.31
PA	0.32	0.29	0.28	0.27	0.265
H	0.34	0.34	0.34	0.34	0.34
PA	0.34	0.295	0.29	0.285	0.275
H	0.36	0.36	0.36	0.36	0.36
PA	0.36	0.325	0.32	0.305	0.295

* H stands for direct hexavalent chromium test; PA for hexavalent chromium test after completing permanganate-azide oxidation for total chromium.

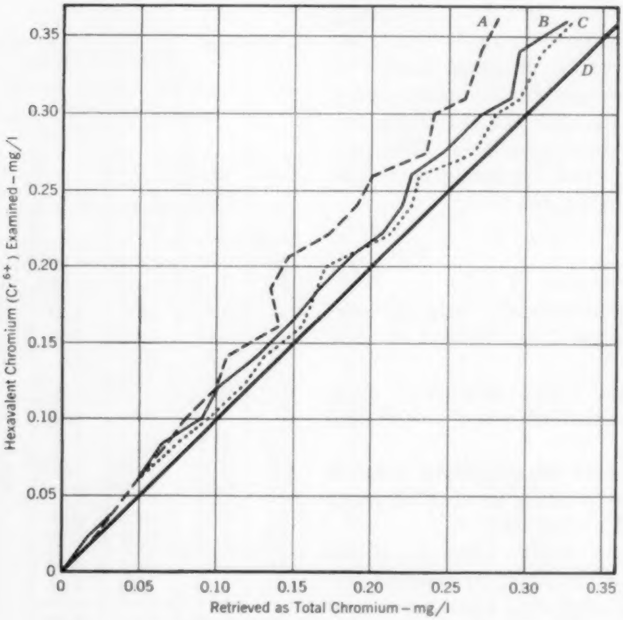


Fig. 1. Comparison of Permanganate Oxidation With Permanganate-Azide Test

Line A *is for permanganate oxidation after 5 min; Line* B *is for permanganate oxidation after 15 min; Line* C *is for permanganate-azide after 5 min; and Line* D *is the complete theoretical retrieve.*

volume with distilled water. Add 2.5 ml of diphenylcarbazide reagent, mix, and compare photometrically at the end of 5 min.

Comparison of Methods

A series of tests were completed with the permanganate-azide procedure on known chromium standards. The data are presented in Table 2. This procedure eliminated several time-consuming operations, among which is a filtration necessary with the *Standard Methods* permanganate oxidation analysis. In order to compare the accuracy of the permanganate-azide method with the *Standard Methods* procedure, the pertinent data is illustrated in Fig. 1.

Here we can observe the discrepancy which exists between a 5- and 15-min reading of the final color reaction using the *Standard Methods* permanganate oxidation can be observed. On the other hand, the permanganate-azide procedure for total chromium produces analytical values of comparable accuracy and precision to the 15-min comparison time of the *Standard Methods* test. The 5-min comparison time with the azide method must be adhered to, because, beyond that time interval, there is a slight fading of color.

Since natural water supplies sometimes behave differently than distilled-water solutions, a series of standards was prepared utilizing a lake water as

the dilutent. The data for this series of tests are shown in Table 3. The effects noted are similar to those observed previously on standards prepared with distilled water.

TABLE 3

Results of Tests Using Lake Water

Test Used*	Amount of Hexavalent Chromium (Cr^{6+}) Present—*mg/l*				
	Prepared Standard	After 5 min	After 10 min	After 15 min	After 20 min
SM	0.05	0.04	0.04	0.04	0.04
PA	0.05	0.045	0.045	0.04	0.04
H	0.05	0.05	0.045	0.05	0.045
SM	0.10	0.08	0.085	0.085	0.085
PA	0.10	0.09	0.085	0.085	0.08
H	0.10	0.10	0.10	0.10	0.10
SM	0.15	0.105	0.125	0.125	0.12
PA	0.15	0.125	0.125	0.12	0.115
H	0.15	0.15	0.15	0.15	0.15
SM	0.20	0.165	0.18	0.18	0.18
PA	0.20	0.18	0.17	0.17	0.165
H	0.20	0.20	0.20	0.20	0.20
SM	0.25	0.17	0.21	0.215	0.215
PA	0.25	0.215	0.21	0.205	0.20
H	0.25	0.245	0.245	0.245	0.245
SM	0.30	0.235	0.275	0.28	0.275
PA	0.30	0.26	0.255	0.245	0.24
H	0.30	0.30	0.295	0.295	0.295

* H stands for direct hexavalent chromium test; SM for hexavalent chromium test after completing the *Standard Methods* permanganate oxidation for total chromium; and PA for hexavalent chromium test after completing the permanganate-azide oxidation for total chromium.

Summary

It has been observed that, by completing a total chromium analysis by the *Standard Methods* permanganate oxidation, the final color reaction with diphenylcarbazide reagent develops slowly over the first 15-min period. This is evident in the higher chromium concentrations. To obtain a higher degree of accuracy and precision with the *Standard Methods* permanganate oxidation, the final color reaction with diphenylcarbazide should be compared photometrically after a 15-min period for maximum color development.

An improved method has been used successfully in determining total chromium. It utilizes sodium azide to reduce the excess permanganate after the necessary oxidation reaction has been completed. This eliminates the use of ammonium hydroxide, additional boiling operation, final filtration, and acidification specified in *Standard Methods.*

The permanganate azide test is a more rapid procedure than that presently specified in *Standard Methods.* The latter method, however, with the recommended time interval for maximum color development, results in a more satisfactory retrieval of known concentrations of chromium ions. The chromium values in Tables 1 and 2, obtained by the direct and theoretical oxidation procedures, reveal a definite deficiency in chromium recovery when oxidation methods are practiced. To obtain accurate results, therefore, it is important that chromium standards be taken through the entire oxidation procedure in parallel with unknown samples.

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Calcium Carbonate Deposition at Iron Surfaces

Werner Stumm

A contribution to the Journal by Werner Stumm, Research Assoc., Swiss Federal Inst. for Water Supply and Sewage Purif., Zurich, Switzerland.

It is generally recognized that calcium carbonate is an important component of the natural protective coatings that are formed in water supply pipes. The quantitative relations that describe the tendency of a natural water to deposit calcium carbonate are expressed by the reversible reaction:

$$Ca^{++} + HCO_3^- = CaCO_3 + H^+ \quad \ldots (1)$$

The equilibrium constant can be derived from the solubility product (K_s) of $CaCO_3$ and the second ionization constant of carbonic acid (K_2). Langelier (*1, 2*) developed a convenient expression for this equilibrium:

$$pH_s = (pK'_2 - pK'_s) - \log (Ca^{++}) - \log (Alk) + \log \left(1 + \frac{2\,K_2}{(H_s^+)}\right) \quad \ldots (2)$$

where (Ca^{++}) is the concentration of calcium ion in moles per liter; (Alk) is the titrable alkalinity in equivalents per liter; (H_s^+) is the hydrogen ion concentration at a hypothetical saturation with calcium carbonate; pH_s is the pH value corresponding to the above hydrogen ion concentration; K_2' and K_s', respectively, are the second ionization constant of carbonic acid and the ion product of $CaCO_3$, corrected for ion activity; and pK_2' and pK_s' are the negative logarithms of K_2' and K_s', respectively. Langelier also introduced the saturation index (S.I.), which equals $pH_{actual} - pH_{saturation}$. This is used as a practical measure of the tendency of a water to deposit $CaCO_3$, and has been a useful guide in water treatment practice. The validity of Eq. 2 has been verified by many investigators. The amount of $CaCO_3$ deposited cannot be predicted by equilibrium data alone, however, because it is dependent upon the relative rates of precipitation from solutions which are supersaturated with $CaCO_3$, and $CaCO_3$ has a strong tendency to remain in supersaturated solution. In the absence of crystallization nuclei, oversaturated calcium carbonate solutions can be preserved for years.

It can be shown that the changes taking place near a corroding iron surface have a considerable influence both on the saturation equilibrium and the precipitation rate of calcium carbonate. According to the electrochemical theory of corrosion, iron goes into solution at the anodic regions of the surface, while hydrogen is deposited at the cathodic regions:

$$2\,H^+ + 2\,e = 2\,H \quad \ldots \ldots (3)$$

The corrosion reaction will continue if hydrogen is removed either by evolution or by depolarization. With oxygen for example:

$$2\,H + \tfrac{1}{2}\,O_2 = H_2O \quad \ldots \ldots (4)$$

Any incipient corrosion will remove

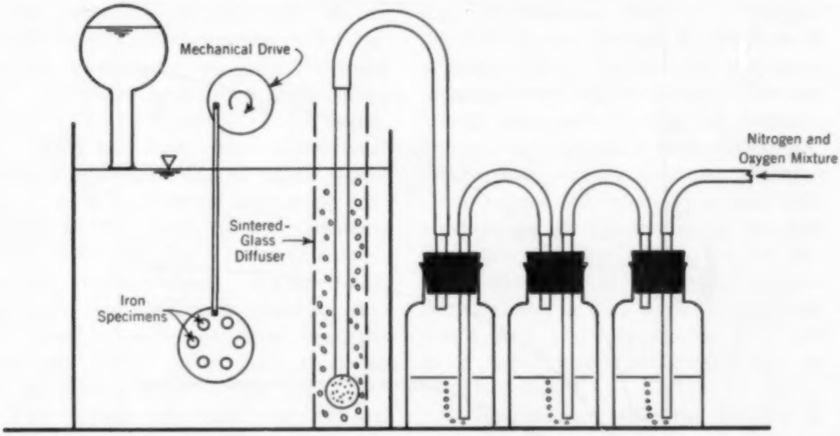

Fig. 1. Circular-Path Apparatus

The iron samples consisted of specimens of cast iron mounted in a rubber disk which moves at a constant velocity through the solution. Mixtures of nitrogen and oxygen were bubbled through the solution to maintain constant concentrations of dissolved oxygen.

hydrogen ions in accordance with the cathodic reaction and will therefore produce an increase in the pH value of the solution near the cathodic regions of the corroding surface. Consequently, the $CaCO_3$ equilibrium will be shifted. It has been shown that $CaCO_3$ can be deposited from calcium bicarbonate solutions in an electrochemical process at the cathode (*3–6*), and the precipitated $CaCO_3$ is directly proportional to the current density.

In the pH range commonly encountered in natural waters, the removal of the hydrogen film is believed to occur mainly by depolarization with dissolved oxygen. The depolarization reaction, and, therefore, the rate of oxygen supply to the cathodic regions of the iron surface, is thought to control the rate of corrosion. On the other hand, the shift in the saturation equilibrium near a corroding iron surface will also become more significant with increasing oxygen concentration.

It would appear to be desirable to have knowledge of the influence of the reactions at the pipe wall upon the rate and other characteristics of $CaCO_3$ precipitation. If $CaCO_3$ is precipitated on the pipe wall, the cathodic reaction will be retarded. The $CaCO_3$ layer will also interact with precipitated iron salts to give a clinging form of ferric oxide rust. According to Evans (*7*) and Haase (*8–11*), a heterogeneous layer of rust and $CaCO_3$ gives a better protection from corrosive attack than does a layer of rust alone or a layer of $CaCO_3$ alone. Although dissolved oxygen is a primary factor controlling the corrosion rate, the secondary effect of increasing the dissolved oxygen is an increase in the extent and the rate of $CaCO_3$ deposition. The relative influence of these opposing effects on the overall corrosion rate is still a matter for debate. In the technical literature of the United States (*12–15*), the general opinion is

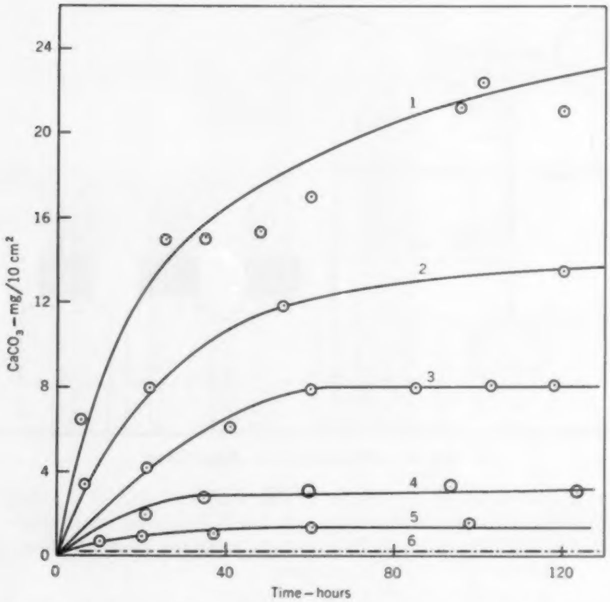

Fig. 2. Influence of pH on $CaCO_3$ Deposition at Iron Surfaces

For Curve 1, pH was 8.40 and S.I. (saturation index) was +1.05; for Curve 2, pH was 7.65 and S.I. was +0.30; for Curve 3, pH was 7.35 and S.I. was ± 0.00; for Curve 4, pH was 6.95 and S.I. was −0.40; for Curve 5, pH was 6.55 and S.I. was −0.80; and for Curve 6, pH was 8.40 and S.I. was +1.05. Curve 6 represents data from tests in which stainless-steel specimens were used instead of cast iron. Ordinate values for Curves 5 and 6 are multiplied by a factor of 3 to make them visible on the graph.

that the primary corrosion-promoting influence of dissolved oxygen is of much more importance than its secondary influence in accelerating $CaCO_3$ deposition, although there are exceptions to this general view (*16*). Therefore, the effort is toward keeping the oxygen concentration as low as possible.

The European opinion, especially as expressed in the German and English literature, is that the secondary influence of dissolved oxygen—the increased and accelerated deposition of $CaCO_3$ and consequent improvement of the protective coating on the metal—is of greater importance (*5–8, 17–19*). In Germany, it is the practice at many plants to aerate the water before it enters the pipeline so that the dissolved-oxygen concentration will be increased. Schikorr (*5*), Haupt (*19*), and others state that an oxygen concentration of at least 6 mg per liter is necessary in order to produce a protective coating. Very little experimental work has been done to test these two opposing concepts.

Considerable confusion seems to exist also in the interpretation of the empirical experience of water works and corrosion prevention authorities. Haase (*8*) and Haupt (*19*), for example, point out that water which produces a protective film at points where the flow is continuous will cause corrosion at the ends of pipe systems where it actually has a lower dissolved-oxygen concentration. Speller (*13*), however, has frequently observed that corrosion is more noticeable near the inlet end of the system and decreases in the outer portions of the lines.

The author has performed a few experiments in order to gain some qualitative knowledge of the characteristics of $CaCO_3$ deposition at iron surfaces. The experimental procedure does not yield conclusions that are immediately applicable to practice, but it can be reasonably expected that the results of these theoretical experiments may lead to further investigations that are of practical significance.

Experimental Method

In corrosion work it is extremely difficult, and possibly not desirable, to attempt to reproduce field conditions in laboratory tests. Systematic experiments demand rigorous control of the important variables. For total-immersion tests these variables are temperature of solution, velocity of movement of solution with respect to the metal, and composition of the solution, including all constituents taking part in the reactions of corrosion or film deposition. It is particularly necessary to maintain constant pH, hardness, alkalinity, dissolved oxygen, and carbon dioxide.

The apparatus used in the tests described here is illustrated diagrammatically in Fig. 1. Specimens of cast iron are mounted in a rubber disk of the same thickness (0.2 in.). The rubber disk moves through the solution at a uniform rate. In this way the specimens are insulated from each other and are in free contact with the solution, but are not exposed to high turbulence. A vertical circular motion without twist causes all specimens, and also all parts of the specimens, to move at the same velocity (*20*). In the experiments cited in this paper a constant velocity of 15.2 m per minute was maintained. The apparatus was held in a constant-temperature room at $19.5°C \pm 0.8°$.

It is important that the volume of the test solution be large enough to avoid appreciable changes in the composition of the solution as a result of the corrosion or deposition reactions. For this reason, the ratio of solution volume to iron surface is maintained at 18 or more liters per 100 sq cm of iron surface. In all experiments the decrease of calcium hardness in the solution due to $CaCO_3$ deposition was observed to be less than 8 per cent. Evaporation loss is made up by a constant-level device.

The test solutions were prepared from distilled water and the only ions present in any quantity were calcium, bicarbonate, and normal carbonate. The solutions were prepared by passing calcium chloride solutions of the desired concentration, slightly acidified with carbon dioxide, through a strongly basic anion exchanger in the bicarbonate form. The chloride content of the effluent was less than 2 mg per liter. To this test solution the radio-isotope Ca^{45} was added at a concentration of approximately 3×10^{-4} millicurie per liter. Ca^{45} is a beta emitter and has a halflife of 152 days. At the concentration used, 1 ml of solution gave about 150 counts per minute on an end-window Geiger tube

mounted in a standard, commercial, lead shield.

Mixtures of nitrogen and oxygen were bubbled through the solution at a constant rate in order to maintain constant concentrations of dissolved oxygen, the composition of the gas mixture varying in accordance with the desired dissolved-oxygen concentration. A sintered-glass diffuser was used to introduce the bubbles at the base of a perforated plexiglass chimney so that there would be no impingement of the stream of gas bubbles on the test specimens. The procedure maintained constant dissolved-oxygen concentration within a 0.3-mg variation per liter.

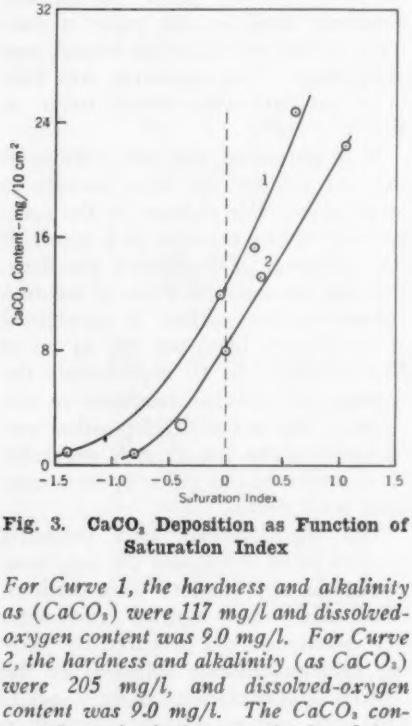

Fig. 3. $CaCO_3$ Deposition as Function of Saturation Index

For Curve 1, the hardness and alkalinity as ($CaCO_3$) were 117 mg/l and dissolved-oxygen content was 9.0 mg/l. For Curve 2, the hardness and alkalinity (as $CaCO_3$) were 205 mg/l, and dissolved-oxygen content was 9.0 mg/l. The $CaCO_3$ content shown for both curves is after 5 days of immersion.

Admixture of the appropriate amount of carbon dioxide in the gas stream served to maintain a constant pH. For test solutions with pH values above about 7.8, the required amount of CO_2 per unit of oxygen-nitrogen mixture became so small that it was difficult to maintain a suitably constant gas mixture. For such cases, the proper CO_2 concentrations were obtained by blowing the oxygen-nitrogen mixture through gas wash bottles filled with concentrated sodium carbonate–sodium bicarbonate solutions. The partial pressure of CO_2 above these solutions increases with the proportion of $NaHCO_3$. In the experiments described, the pH of the test solutions remained constant within 0.07 pH

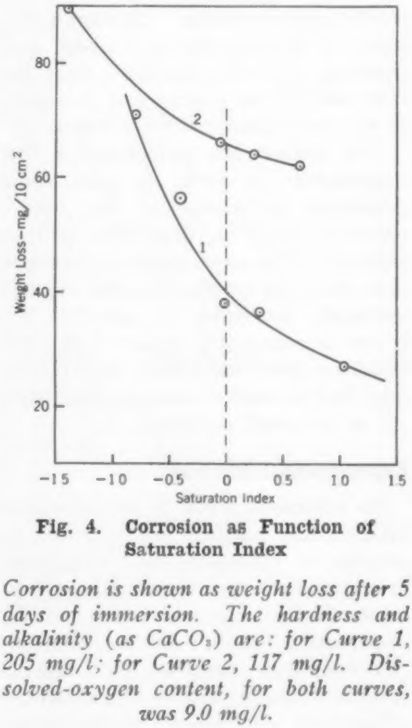

Fig. 4. Corrosion as Function of Saturation Index

Corrosion is shown as weight loss after 5 days of immersion. The hardness and alkalinity (as $CaCO_3$) are: for Curve 1, 205 mg/l; for Curve 2, 117 mg/l. Dissolved-oxygen content, for both curves, was 9.0 mg/l.

TABLE 1

Formation of Film and Weight Loss Caused by Corrosion After 5 Days

Composition of Water Used				Film Weight *mg/10 cm²*	$CaCO_3$ in Film Composition %	Weight Loss *mg/10 cm²*
Hardness as $CaCO_3$ *mg/l*	pH	Saturation Index	Dissolved Oxygen *mg/l*			
205	8.40	+1.05	9.0	87	26.4	27
205	7.65	+0.30	9.0	96	15.7	36.5
205	7.35	±0.00	9.0	75	10.6	38
205	6.95	−0.40	9.0	82	4.0	56
205	6.55	−0.80	9.0	85	0.6	71
205	8.40	+1.05	5.2	82	22.0	21
205	8.40	+1.05	2.6	60	24.8	20.5
205	8.40	+1.05	1.1	50	22.0	20
205	7.65	+0.30	4.9	79	13.8	29.5
205	6.55	−0.80	4.2	40	0.9	36
117	8.40	+0.60	9.0	132	18.7	62
117	6.40	−1.40	9.0	86	0.8	90
117	6.40	−1.40	5.4	38	1.2	65.5

unit. The pH and dissolved oxygen were periodically checked each time.

The iron specimens used in the experiments were disks, about 0.2 in. thick, cut from a cast-iron rod. Before the experiment, the specimens were cleaned by immersing for 5 min in 0.1-m HCl solution, washing with oxygen-free water, rinsing with acetone, drying, and polishing with an emery wheel. They were then weighed, after storage for 24 hr in a desiccator.

The amount of $CaCO_3$ deposited was determined radiochemically. The iron specimens fitted exactly into the steel cup planchets used with the available automatic scaling equipment. It was possible, therefore, to measure the activity of the deposit directly on the specimens without removing the film from the iron surface. In each test solution, the ratio of measured counts, caused by radioisotope Ca^{45}, to the total calcium concentration was determined. The activity of the solution was measured by evaporating known volumes (for example, 1, 2, and 5 ml) from the surface of iron specimens of the same kind as those used in the experiments. The disks were heated by means of an infrared lamp in order to evaporate the solution on the surface. The activity of these calibration samples was measured together with the test specimens using Geiger-Muller tubes with thin end-windows (of less than 2-mg per square centimeter mica) and automatic scaling equipment. Background was counted alternately with the samples. The total Ca^{++} concentration of the test solution was determined by titration with ethylenediaminetetraacetate using murexide as an indicator.

In order to investigate whether the film thickness influences the experimental results because of increased self-absorption, some standard samples were made by preparing deposits of a known amount of Ca^{45} and different amounts of inert iron oxide, and then determining the number of counts. The results indicated that the measured activity is relatively independent of the film thickness up to values of approximately 80 mg of film per 10 sq cm.

Because the ratio of activity to total calcium concentration in the test solution is known, the measured number of counts given by the test specimens is representative of the amount of deposited calcium. All values of deposited calcium can be reasonably expressed as $CaCO_3$, assuming that the calcium component in the film is mainly $CaCO_3$. This was found to be true by making individual carbonate determinations (titration with HCl) on a few deposits.

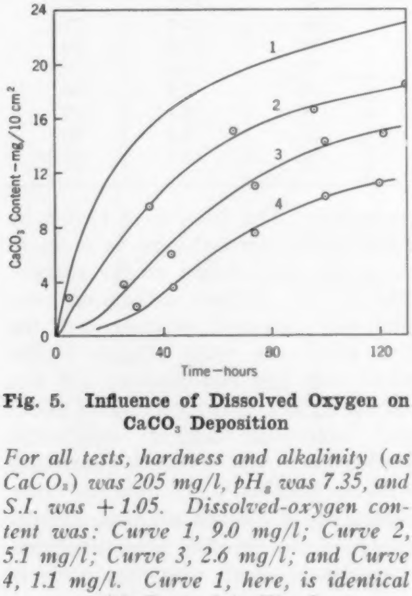

Fig. 5. Influence of Dissolved Oxygen on $CaCO_3$ Deposition

For all tests, hardness and alkalinity (as $CaCO_3$) was 205 mg/l, pH_s was 7.35, and S.I. was + 1.05. Dissolved-oxygen content was: Curve 1, 9.0 mg/l; Curve 2, 5.1 mg/l; Curve 3, 2.6 mg/l; and Curve 4, 1.1 mg/l. Curve 1, here, is identical with Curve 1 in Fig. 2.

Preliminary tests indicated that the determination of $CaCO_3$ could be reproduced within 5 per cent. Each specimen yielded two values, one from each side. The agreement between these two values was uniformly good. One preliminary immersion experiment was run simultaneously in two separate jars under the same experimental conditions. Within a time period of 5 days, the experimental results of both tests were practically identical. This was considered to be sufficient justification for running individual rather than duplicate tests.

The degree of corrosion was measured by determining the weight loss of the specimens. The specimens were washed with oxygen-free distilled water, rinsed with acetone, and dried in a desiccator. The corrosion products and the deposited $CaCO_3$ were removed mechanically and the specimens were weighed.

The duration of such experimental laboratory tests is important. Usually, the initial corrosion rate is much greater than the average rate for an extended period. The test period cannot be extended indefinitely, however, because the accumulation of corrosion products in the test solution may affect the corrosion reactions. For this reason, the tests were limited to 5 days. In order to keep the concentrations of Fe^{+++} in the solution as low as possible, a small amount of cation exchanger, previously brought into equilibrium with Ca^{45}, was added to the test solution. The exchanger removed Fe^{+++} as formed, substituting Ca^{++}.

Influence of pH

The experimental results are summarized in Figs. 2–7, and in Table 1. Figure 2 shows the results of a series of experiments on a water with an initial hardness and alkalinity of 205 mg/l as $CaCO_3$, pH_s of 7.35, and a dissolved-oxygen concentration held constant at 9.0 mg/l. Time of immersion was 5 days. In the individual experiments the pH values ranged from 8.40 to 6.55. The results are plotted in terms of the amount of $CaCO_3$, deposited at an iron surface of 10 sq cm, against time of immersion. The plot shows that with increasing pH, increasing amounts of $CaCO_3$ are deposited. In

a water with a pH of 8.40 the deposition on the specimen amounted to 23 mg $CaCO_3$ on 10 sq cm after an immersion of 5 days. An additional test (Curve 6 in Fig. 2) was run at the same pH in which stainless-steel specimens were used instead of cast iron. In this test, practically no $CaCO_3$ was precipitated at the stainless-steel surface in 5 days even though the saturation index was + 1.05 pH unit. This effect shows that deposition reaction may be considerably influenced by corrosion reaction at the iron surface. The shift of pH value which occurs near the cathodic regions of the corroding surface is also demonstrated by the fact that even at negative saturation indexes (Curves 4, 5) appreciable amounts of calcium carbonate are precipitated.

Saturation Index

Figure 3 shows the results of this series of experiments and of another series with different hardness and alkalinity content, the results being plotted in terms of the amount of $CaCO_3$ deposited in 5 days against the saturation index. It is evident that no discontinuity or change in trend occurs at a saturation index of zero.

In Fig. 4, the amount of corrosion, as measured by weight loss, is shown in relation to the saturation index. There is an obvious decrease in the corrosion rate as the saturation index increases. Since many investigators have shown that the influence of pH change alone on corrosion is insignificant in this range of pH values, it is believed to be safe to assume that the change is caused by differences in the formation of protective films.

Buffer Capacity

Buffer capacity may be expressed in terms of the amount of strong base required to produce a unit change of pH in the solution.

In soft waters with low alkalinity, the buffer capacity is low. The corrosion reaction is therefore able to produce more significant increases in the pH value near the metal surface. It will be noted in Fig. 3 that, at the same pH value, the soft water (Curve 1) precipitates more $CaCO_3$ than the harder water (Curve 2). The observations of many investigators are in agreement on this point. Ryznar (*21*), for example, points out that the deposition of calcium carbonate is more de-

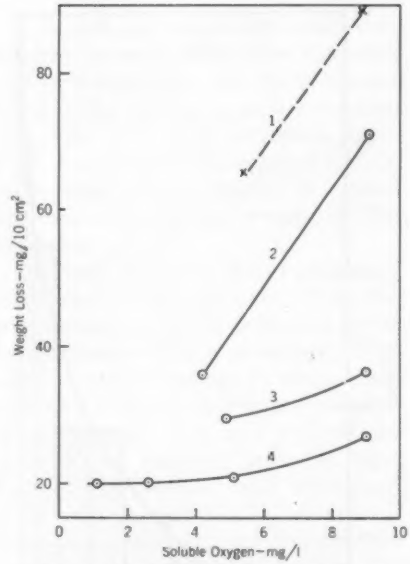

Fig. 6. Corrosion as a Function of Dissolved Oxygen

Corrosion is shown as weight loss after 5 days of immersion. For Curve 1, hardness and alkalinity (as $CaCO_3$) was 117 mg/l, pH was 6.40 and S.I. was − 1.40. For Curve 2, pH was 6.55, and S.I. was − 0.80. For Curve 3, pH was 7.65 and S.I. was + 0.30. For Curve 4, pH was 8.40 and S.I. was + 1.05. Hardness and alkalinity (as $CaCO_3$) was 205 mg/l for Curves 2–4.

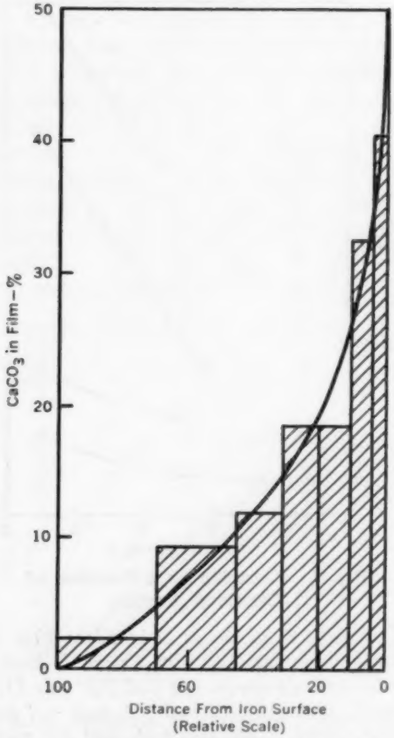

Fig. 7. Changes in Film Composition With Distance From Surface

The $CaCO_3$ content was obtained after a 4-day immersion in water having 205 mg/l hardness and alkalinity (as $CaCO_3$), dissolved-oxygen content of 9.0 mg/l, and pH of 8.40.

pendent on the pH_s of saturation than on the saturation index. He proposes a stability index, $S = 2pH_s - pH_{actual}$, which he believes to be a better indication of the expected amount of $CaCO_3$ deposition. This empirical stability index gives more weight to the saturation pH than does the Langelier index. The saturation pH is to some extent a function of the buffer capacity.

It is a well known fact that corrosion rates are usually lower in hard waters than they are in soft waters. In spite of the greater deposition of $CaCO_3$ in the softer water, there were also higher corrosion rates, as shown in Fig. 4. From this it appears that the thickness of $CaCO_3$ deposit, alone, is not sufficient for corrosion protection. A possible inference is that the crystalline state of the precipitated $CaCO_3$ and iron salts is also of importance. It may be that, in a soft water, $CaCO_3$ is deposited in a more amorphous state than it is in hard waters, and that, in the soft water, the precipitated iron salts show a different structure than in a hard water. It can be further inferred, that in the presence of greater amounts of electrolytes, colloidal iron hydroxide is more rapidly precipitated on the iron surface because of reduction of the zeta potential. As a partial confirmation of these inferences, it was found that in the hard water (205 mg/l) at a pH of 8.40, 95–100 per cent of the iron lost in corrosion was found in the surface film, whereas in the softer water (117 mg/l), at the same pH, only 67–73 per cent of the iron appeared in the film.

Dissolved Oxygen

Figure 5 shows the $CaCO_3$ deposition from the hard water (205 mg/l) at a pH of 8.40 and at different oxygen concentrations. This plot clearly shows that dissolved oxygen plays an important part in the deposition of $CaCO_3$. The amount of $CaCO_3$ deposited increases substantially as dissolved-oxygen concentration increases.

Figure 6 shows the loss in weight caused by corrosion in a series of experiments using both the hard and the soft waters, with variations in pH, saturation index, and dissolved-oxygen concentration. In the absence of film formation, the amount of corrosion would be expected to increase with increasing oxygen concentration. That

this occurs is shown in the experiments illustrated by Curves 1 and 2 (Fig. 6), where the formation of protective films is negligible because the saturation indexes are negative. In the experiments illustrated by Curves 3 and 4, where positive saturation indices were maintained, the influence of dissolved-oxygen concentration is relatively insignificant. One must also consider that the films do not build up to a maximum of protection in the short period of 5 days. These 5-day experiments, however, do permit the assumption that in natural waters which are saturated with $CaCO_3$ dissolved oxygen may, under certain conditions, have no accelerating influence upon the corrosion rate because it also promotes film formation. Furthermore, these experiments do not by any means exclude the possibility that, over a longer period, waters relatively high in oxygen concentration will produce better protective coatings on corrodible ferrous metals than the same waters which are low in dissolved oxygen. Therefore, a decrease in corrosion will be observed with increasing dissolved oxygen.

Film Composition

One might reasonably expect some correlation between the properties of the water and the composition of the film and also between the thickness and composition of the film and the protective character of the coating. Table 1 gives the amount and composition of the film formed in a number of the experiments. The iron oxide in the coating was usually found to contain 6 molecules of water per molecule of Fe_2O_3 after drying in a desiccator. It is assumed that, during the storage of the corroded specimens in the desiccator, any bivalent iron was converted into the trivalent state.

It is difficult to establish much correlation between either film thickness or film composition and the protective effect of the coating against corrosion. The data give some indication, however, that a high proportion of $CaCO_3$ in the film is more effective in retarding corrosion than an increase in film thickness.

Calcium carbonate is not uniformly distributed within the film. The relative amount of $CaCO_3$ is highest in the layers closest to the iron surface. Figure 7 shows the change in composition of a typical film with distance from the metal surface. For this analysis the coating was removed layer by layer by scraping carefully with sandpaper. It is evident that $CaCO_3$ is precipitated in the greatest proportion in the zone nearest to the metal surface, and inside the layers composed primarily of iron oxide. This is taken by the author as an additional piece of evidence that the deposition of $CaCO_3$ is largely controlled by the electrochemical changes at the metal surface.

Summary and Conclusions

A technique for studying rates of corrosion and formation of protective films has been developed, which allows maintenance of reasonably constant water composition, dissolved-oxygen content, saturation index, and other factors important in corrosion. The device allows constant change of the water film in contact with the metal, without inducing excessive turbulence. Techniques have been devised for removing ferric ions from solution as soon as formed, and for using radioactive Ca^{45} to study the formation of calcium carbonate films.

The experimental results indicate that, because of electrochemical corrosion reaction, an iron surface has a considerable influence on the pH and

on the $CaCO_3$ equilibrium in the water layers near it. The amount of deposited $CaCO_3$ at an iron wall is dependent upon the saturation index, the buffer capacity, and the dissolved-oxygen concentration of the water. The results show that the corrosion-accelerating influence of dissolved oxygen may become insignificant in waters having positive saturation indexes, because the rate of formation of protective films is also increased as the dissolved oxygen increases.

Acknowledgments

These investigations were conducted by the author while in residence as a special student of sanitary engineering in the Division of Applied Science (now the Division of Engineering and Applied Physics) at Harvard University, Cambridge, Mass.

The author wishes to express his appreciation for the assistance and encouragement given him by members of the sanitary-engineering faculty, and, especially, Edward W. Moore, who aided in preparing this paper.

The author also wishes to acknowledge his indebtedness to the authorities of the Swiss Institute for Water Supply, Sewage Purification and Water Pollution Control, and the Federal Institute of Technology, both at Zurich, Switzerland, for granting the leave of absence that made these studies possible.

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Report of the Committee on Water Works Administration

For the Year Ending December 31, 1955

A report of the activities of the Committee on Water Works Administration for the year ending Dec. 31, 1955, submitted to the AWWA Board of Directors on Jan. 16, 1956, by Wendell R. LaDue, Chairman.

As outlined on pages 45–46 of the 1955 AWWA *Directory* (Reference Edition), the present organization of the Coordinating Committee on Water Works Administration provides for 29 subcommittees, grouped in four classifications, with about 120 members of the Association participating. The general committee consists of the chairman, the general chairmen of the four groups, and the chairmen of the various active subcommittees. Other members of the various subcommittees are not members of the Committee on Water Works Administration. Committee work has been broadened by the creation of "task groups." The chairman of a task group is not a member of the Committee on Water Works Administration, but, in general, works within the province of the Division under which the task group functions. When the work of the task group covers activities in various Divisions, however, the chairman becomes a member of the committee. The present committee personnel are:

W. R. LaDue, *Chairman*

F. C. Amsbary Jr.	M. P. Hatcher
L. E. Ayres	H. E. Hudson Jr.
J. J. Barr	A. P. Kuranz
E. L. Bean	R. J. McLeod
E. S. Cole	J. H. Murdoch Jr.
M. B. Cunningham	L. A. Smith
	L. N. Thompson
E. L. Filby	A. A. Ulrich
L. S. Finch	W. V. Weir

R. J. Faust, *ex officio*

Personnel and Organizational Changes

Committee activities and personnel have been subject to continual study. At its June 1955 meeting at Chicago, the Board:

1. Accepted the recommendations of the Committee on Uniformity of Grading, Registration, and Short Courses that it be retitled "Committee on Education"; that Chairman Faust, A. P. Black, E. S. Hopkins, Fred Merryfield, and E. R. Stapley be continued on the committee; and that I. N. Ronhovde, of Texas A&M College, be added to it.

2. Authorized the reactivation of the Committee on Joint Administration of Water and Sewer Facilities. Leonard N. Thompson, who was chairman of the previous committee, has accepted the task of cochairman, along with Cochairman R. J. McLeod.

3. Approved the assignment of the following individuals to the Committee on Water Use: H. E. Hudson Jr. (chairman), Stephen Bergen, F. W. Davenport, R. W. Haywood Jr., L. L. Hedgepeth, W. J. O'Connell, S. T. Powell, Kenneth Watson, and C. V. Youngquist.

4. Accepted the third interim report presented by Chairman John H. Murdoch Jr. on the activities of Committee 2240 M, together with its recommendation to continue to cooperate with the subcommittee of the Engineering Committee of NARUC on wa-

ter service rules, especially in regard to rewriting Article V (Measurement of Services), and also to continue with the effort to have other sections brought more in harmony with the ideas and policies of AWWA.

Inactive Subcommittees

The following subcommittees are now inactive or have not been activated:

4110 M—Constitutional and Statutory Aspects of Municipal Water Works Organization

4150 M—Taxation and Revenue Allocation (task group active)

4220 M—Management Relations

4230 M—Compensation of Water Works Personnel (adviser retained)

4310 M—Construction, Equipment, and Materials Contracts

4320 M—Valuation and Depreciation

4330 M—Cost Trends

4410 M—Water Department Reports (adviser retained).

1955 Conference

At the 1955 Conference at least fifteen principal topics stemming from the committee's activities, either directly or indirectly, were presented at the various sessions. Attendance at the sessions was good and member interest was unusually high. In fact, the open session of the Committee on Water Works Administration attracted the highest attendance of any session of the Conference.

Subcommittee Activities

The continuing and growing interest in the field of water works management and administration is evidenced by the steady flow of inquiries into AWWA headquarters regarding committee activities. These questions cover a wide variety of subjects, indicating a need for studied, increased, and continuing activity in all phases of the committee's present field of endeavor and expansion into other fields as the AWWA program will permit and as the membership requires.

The following is a brief summary of the activities of the several subcommittees during 1955:

4120 M—Radio and Mobile Communication Facilities for Water Works. Committee activity in 1955 consisted largely in advising water utilities of the value and savings in the cost of operations to be gained by the use of mobile radio communications. Through the efforts of the AWWA office, a rather comprehensive collection of material from the various sections has been collected to support the National Committee on Utilities Radio in its protest to the Federal Communications Commission. FCC has indicated that it will take under consideration the licensing of additional radio frequencies now allocated to the national radio band. Hearings are expected to be announced by FCC in the near future. There is a danger that channels will be split and assignments of wavelengths changed.

It is recommended that AWWA continue its interest in the FCC hearings and take a more active part in the affairs of NCUR. If FCC should hold a hearing and announce its decision, it is believed this would be of general interest at the St. Louis Conference, but could be handled as a brief report during the meeting of the Committee on Water Works Administration.

4130 M—Water Use in Air Conditioning and Other Refrigeration. This committee has been reactivated to study continuing problems. The industry is expanding so explosively that it now

affects, or will soon affect materially, practically every water works in the country. It is felt that the committee will be doing a real service if it gleans information, analyzes and summarizes it, and brings it to each water works man through the medium of the JOURNAL. Various phases and problems that should be covered include: [1] trends and predictions as to growth; [2] water problems resulting from refrigeration; [3] costs involved to water works; [4] rate structure developments; [5] means of encouraging water conservation; [6] regulations and regulatory methods; and [7] court actions and opinions. Items 4, 5, and 6 should receive major emphasis and may require the aid of other committees, particularly 4420 M.

The 1955 report of Committee 4130 M [published in the November 1955 JOURNAL] contained a tabulation of the types of control of air-conditioning water use exercised by a number of cities. This information was obtained from a questionnaire sent out in the spring of 1955. It is believed that a summary and analysis of the various regulatory methods and procedures employed, together with some examples of regulations, would serve a useful purpose.

Continued checking and correction of data are necessary in order to keep abreast of rapid changes with regard to regulations. There is still a lack of specific information in many cities as to what definitely constitutes the connected loads. It is believed that a proper understanding of the impact of air conditioning upon "load growth" is yet to be clearly defined, acknowledged, and accepted.

4140 M—Water Use in Fire Prevention and Protection. As a result of the work of this committee there was a review of data required by the National Board of Fire Underwriters, as well as a discussion on fire protection rate problems at the 1955 Conference [published in the December 1955 JOURNAL]. With the information at hand, the committee is in a position to set up a continuing program embracing rate classifications, evaluation, and coverage. The committee was advised to examine the possibility of recommending that charges for private fire protection be assessed on the basis of area rather than size of connection to the distribution system.

4150 M—Taxation and Revenue Allocation. Although this committee is not yet formed, AWWA has had occasion to present the water works viewpoint on the important subject of payment of charges due to relocation of facilities resulting from highway construction. A congressional hearing was held on Jul. 7, 1953, by the Subcommittee on Roads of the House Public Works Committee. A strong presentation on behalf of relief legislation was made by representatives of the National Association of Railroad and Utilities Commissioners, the National Institute of Municipal Law Officers, and telephone, gas, electric, telegraph, and street railway groups. Harry B. Shaw, of the Washington Suburban Sanitary District, appeared for the water works industry and filed a statement. This problem remains constantly before water works managers as a stepped-up program of superhighways and turnpikes develops and continues to expand, encouraged by current federal highway program legislation. Evidence is present that, in some areas, aid has been given in the following ways: [1] direct monetary assistance; [2] inclusion in contracts of a portion of the changes to be made;

and [3] furnishing of both labor and material as part of the highway construction contract.

4210 M—Public Relations. Routine assistance has remained available to the AWWA staff in the preparation of *Willing Water.*

Committee personnel exerted every effort in promoting the issuance of a stamp commemorating the 75th anniversary of AWWA. The Post Office Department, however, failed to approve the request.

4230 M—Compensation of Water Works Personnel. The committee submitted a final report in 1954. AWWA headquarters has evaluated a survey of employment conditions, made in March 1954, which proved basic in directing the future activities of this committee. From the survey, it is obvious that a great deal can be gained by a better understanding of the interrelationships of employee tasks in a single utility. Results of the survey, which prove both gratifying and confusing, were published in the May 1955 JOURNAL.

A task group (2210 M) has been formed to study job classifications. Work is being carried out under the jurisdiction of the Water Works Management Division.

4240 M—Pension and Retirement Plans. Pressure to place state pension systems under the Federal Social Security Act continues. National attitudes toward all types of pension systems will affect the water works field and will bear constant attention.

4250 M—Safety Practices. The main activity of the four subgroups of this committee has been the preparation of a safety manual, which was published serially in the JOURNAL (July–December 1955) and is being reprinted under its own cover.

The committee is also preparing an award program to be used as an incentive for achieving outstanding safety results. The awards, as presently conceived, are on a sectional as well as a national (or international) basis. The development of an award system has been difficult because of the many factors involved. It is hoped that the award plan may be completed in time for review by the Committee on Water Works Administration at the St. Louis Conference.

The *Manual* is applicable to small, as well as large, water utilities. Safety in water works is creating very great member interest and more active participation than any other phase of water works personnel management. The committee shows excellent interest and is to be complimented greatly upon its high-level activity. The need for safety committees at the section level must be stressed at every opportunity.

Water has now taken its place with electricity, gas, and communications as a component part of the Utilities Section of the National Safety Council.

4260 M—Education. Six short-course outlines prepared by the committee were published in the October 1955 *Willing Water.* These outlines are to form the basis of six short-course training manuals. The work on the manuals is about ready to start, provided a suitable development staff can be assembled. The committee hopes to assign not more than three members located in the same geographical area to write and be responsible for each manual. The problem will be to get persons with prior teaching experience to accept the writing assignments. The committee hopes to produce at least one manual each year. If the work is properly handled and scheduled, more progress may result.

The committee would appreciate the approval and support of the Committee on Water Works Administration and the Board in the development of training manuals to cover the following six subjects: [1] basic water works operation; [2] advanced general water works operation; [3] ground water production and treatment; [4] surface water production and treatment; [5] water distribution; and [6] water works management.

4310 M—Construction, Equipment, and Materials Contracts. Although no committee activity is in progress, it is of interest to note that the Association's attention has been directed to the recently released "Uniform Public Works Engineering Construction Forms," prepared jointly by the American Public Works Association and the Associated General Contractors of America. The eral Contractors of America. The forms cover such items as invitations to bid, instructions to bidders, proposals, agreements, and general conditions of contract. It is expected that this document will merit review. A standby policy is recommended, as AWWA was not a participating agent.

4340 M—Water Main Extension Policy. This committee has been continuously active. With the population trend producing suburban development, public service commission policies on main extensions will bear close watching, as will the effect of the trend toward urban redevelopment. The present thinking of the committee is to recommend that extensions be made upon the basis of dollar value of the installation required rather than the number of feet per customer to be served.

A questionnaire was developed for use in determining all utility commission regulations or policies regarding main extensions. Questions were included to reveal the general extent of control exerted over operations of water utilities, both municipally and privately owned. After completion of this survey and before the 1956 Conference, it is planned to attempt to get the committee to agree upon a method, or methods, of computing free extensions and making refunds which can be offered as an AWWA recommendation. As extension of mains depends upon so many local conditions and traditions, it is felt that perhaps no uniform policy could receive general acceptance. The entire subject is of direct, pertinent concern to members.

4420 M—Water Rates. Reports of the meritorious activities of this committee have appeared in the Journal and have been given at AWWA conferences. The committee deserves high commendation for continuing an arduous and lengthy job. It is presently on a standby basis, although review and revision of water rates under changing economic conditions are necessary parts of the proper administration of a healthy water utility. The widespread use of air conditioning poses a problem in rates. The control of the funds provided by rates is also a matter for constant surveillance, to insure that the water utility may receive and use its own funds as necessary for successful operation and expansion.

4430 M—Joint Administration of Water and Sewer Facilities. This committee has recently resumed active status. With the general acceptance of the sewerage service charge and its almost universal collection by the water utility office, the trend toward joint administration is expanding, with attendant problems. The AWWA office will initiate the mailing of a ques-

tionnaire to cities of 10,000 or more population to determine information of value to the committee. It is indicated that this information will probably be available before the end of 1956. No action will be taken by the committee pending the receipt of these data.

4440 M—Water Use. The two groups, 4441 M (Industrial) and 4442 M (Residential and Commercial), are now combined under the chairmanship of H. E. Hudson Jr. The committee's task may be defined briefly: It will continue its studies of the effects of geography and the kinds of water needed to fill industrial requirements, and will outline the various schemes for industrial water conservation. It will study the various trends and demands of domestic (residential) uses, with particular stress upon the causes of per capita increases and seasonal and hourly variations. Although residential requirements may at present appear to be the paramount factor in public water supply systems, industrial requirements may, in the long run, become far more important for future planning. The many divergent uses of water will, in time, produce areas of conflict, requiring careful analysis of the possible priority of use of some supplies.

Studies on population and water use trends have been in progress and should be completed during the coming spring by Ross Hanson, of the Illinois State Water Survey. These data indicate a number of factors, not hitherto taken into account in water use forecasts, that may cause upward revision of estimates for the period 1960–70.

4450 D—Revenue-producing Water. This committee is being expanded and an attempt is being made to arrive at a more descriptive name. Outlining of procedure is under way. The committee works in the field of interest of the Water Distribution Division, which is giving valuable assistance and impetus. It is suggested that, instead of being included in a single large handbook, the various subdivisions of the topic be published in a series of individual manuals. Each manual would be a comprehensive assembly of papers on related matters, with care taken to eliminate duplication and extraneous material. The work would be evaluated through committee action to bring any particular subject into proper focus. The manual should also contain a comprehensive bibliography of the subject covered. By this means, manuals of specific interest could be prepared and sold at low cost.

Research and Development Groups

2210 M—Job Classifications. This task group is in the province of the Management Division and is just getting under way. It will be helpful to Committee 4230 M (Compensation). Chairman R. S. Millar states that he is making considerable progress on the work of this committee and expects to present a progress report at the St. Louis Conference.

2220 M—Review and Redevelopment of a Rating Scale for Water Works. The task group has recently been enlarged by the appointment of two new members, C. P. Abraham and R. W. Kean. A round-table conference of the group has been scheduled to review the work already done and to plan for the future. Chairman J. H. Murdoch Jr. and other members, in speaking before AWWA sections and other interested water works groups, have always taken the opportunity to talk about the value of the work of this task group. It is believed that the work will require several years before

anyone can say that it is "approaching" completion. So far, it has been determined that the task group will concern itself with the following general matters: [1] financing, rate structures, and metering; [2] general and customer accounting, collecting and billing, and recording of data; [3] managerial responsibility and authority, and personnel training; [4] source of supply, transmission, and provision of pressure; [5] purification and treatment; and [6] distribution. Task groups are being set up for all of the foregoing subdivisions. An attempt is being made to select members in the same geographical area, so that the members can consult with one another on two or more occasions before the St. Louis Conference.

2230 M—Committee to Cooperate With NARUC Committee on Revision of System of Accounts for Water Utilities. The committee has continued its work throughout 1955 and has met with representatives of the NARUC committee. A revised draft of the "Uniform System of Accounts for Water Utilities" was prepared, and copies were released on Dec. 30, 1954. The AWWA committee has worked earnestly and hard for more than 2 years in an attempt to bring the system of accounts promulgated by NARUC into a realistic relationship with the construction and operating practices of water works utilities. Although the rules are mandatory only upon the operators of privately owned utilities, the classification of accounts is extensively used in publicly owned systems. The work of the committee was brought to a conclusion and Chairman J. J. Barr of the AWWA group was requested to provide NARUC with about 700 copies of the finished document for consideration by the various state public service commissions prior to the adoption of the report as a formal document by NARUC. Chairman Barr was advised by Chairman Colbert of the NARUC group that the electric and gas utility associations had similarly provided copies of their reports. The fact that the water works industry is principally publicly owned, in contrast with the electric and gas industries, which are principally under private ownership, did not appear to have much effect upon Chairman Colbert's opinion. As there was considerable pressure to get the reports ready for approval, AWWA headquarters was authorized to have the documents prepared, and the matter of defraying the cost was referred to the Executive Committee of the AWWA Board. The majority of the members of the Executive Committee were willing to have AWWA bear the expense temporarily, provided that an effort were made to set up a publication and sales procedure with NARUC, which would enable AWWA to publish and sell the material and, in due time, recover the cost of the investment. The Board approved the addition of $2,250 in a budget account for 1955 to cover the cost of preparing and shipping preprints of the NARUC document.

At the January 1954 meeting of the AWWA Board the major changes proposed in the new draft were reported. It was evident that many of the Directors felt that the provisions with respect to depreciation were objectionable, and the NARUC representatives were so advised. As a result of what might be termed a uniform front on the part of the water industry, the NARUC representatives have agreed at this time to maintain substantially the same definition of depreciation as that contained in the presently effective system of ac-

counts. The AWWA committee was unanimous in its belief that the new system contains many favorable changes and that its adoption should be sanctioned.

The AWWA committee's approach to the problem is excellent.

2240 M—Committee to Cooperate With NARUC Committee on Proposed Rules and Regulations Governing Water Service. On Oct. 8, 1953, copies of the rules and regulations under consideration by the NARUC Committee on Engineering were submitted to the AWWA Officers and Directors as a report of committee progress. The AWWA committee is attempting to cooperate with the NARUC Engineering Committee, and several conferences have been held. The AWWA committee will not, however, go along with ideas which it cannot approve. The only active work in progress is the study of proposals for revisions of standard rules and regulations by the California and Arkansas public utility commissions. The AWWA committee intends to keep in touch with all such proposed revisions and with the work of the NARUC committee.

It is believed that the work of the NARUC committee is probably approaching completion. The AWWA committee should be continued, however, to study detailed proposals in the various states, implementing the proposals of the NARUC committee.

A committee of the California Section of AWWA, under the chairmanship of W. C. Welmon, is cooperating with the California Public Utility Commission in the preparation of standard rules and regulations for water utilities. A report from Chairman Welmon would be of value at the St. Louis Conference.

Chairman Murdoch and his committee are performing an arduous task well.

Recommendations

The attention of the Board is again directed to the necessary enlarging of the activities of the Committee on Water Works Administration along several lines, as previously noted. There are numerous projects of the general committee which cannot be handled efficiently strictly on a member committee basis. They involve a large amount of research and could best be handled as staff projects. The AWWA budget might be supplemented by outside funds, especially when the project involves items in which manufacturers or other industries are vitally concerned. The activities which might be considered as projects requiring staff aid are those of Subcommittees 4110 M, 4150 M, 4230 M, 4260 M, and 4450 D, and Task Groups 2210 M, 2220 M, 2230 M, and 2240 M, as described above.

It is the aim of the Committee on Water Works Administration to proceed deliberately, acting upon and anticipating obvious member demands and expanding interests; to establish a long-term policy of continuing activities; to maintain close cooperation with the Committee on Water Works Practice; and to encourage member participation in task groups of the various Divisions. Appreciation is hereby extended to personnel of the AWWA office and to all committee chairmen and members for the many services rendered. The ever-valued counsel, consideration, and advice of the members of the Board of Directors are gratefully acknowledged.

Report of the Committee on Water Works Practice

For the Year Ending December 31, 1955

A report of the activities of the Committee on Water Works Practice for the year ending Dec. 31, 1955, submitted to the AWWA Board of Directors on Jan. 16, 1956, by Louis R. Howson, Chairman.

THE year 1955 has been unusually productive of important material by subcommittees operating under the jurisdiction of the Committee on Water Works Practice. Specifications for rubber-seated butterfly valves have been amended and those for metal-seated butterfly valves have been approved for publication. The Committee on Deep Well Pumps, operating under ASA procedure, has developed, and the Association has published, American Standard Specifications for Deep Well Vertical Turbine Pumps. An important revision has been made in the Standard Specifications for Reinforced Concrete Water Pipe, Steel Cylinder Type, Prestressed. Specifications for water treatment chemicals have continued to be developed under the leadership of James E. Kerslake. At the end of the year, the discussions on the specifications for copper sulfate have reached a point where the document could be submitted to the Board for approval prior to publication in the JOURNAL.

Specifications and Manuals

Cast-iron pipe and fittings. The work of the ASA A21 Committee in the field of cast-iron pipe and fittings, under the outstanding leadership of Thomas H. Wiggin, has brought the revision of the Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe (ASA A21.1; AWWA C101) to completion. The document is now in the hands of the printer.

There appears to be a tendency on the part of some salesmen for cast-iron pipe to recommend the installation of this material with a higher tensile strength and thinner wall than is listed in the specifications. These deviations in tensile strength and wall thickness appear to be consistent with the language of A21.1, but such recommendations are made at times without the specific advice of a competent consulting engineer concerning the propriety of such deviations. When the question is referred to the office of the Secretary of the Association, advice is given that such purchase should be made only when a consulting engineer, competent in the metallurgical field, is acquainted with the conditions under which the pipe is to be installed and recommends such installation. It is also advisable for the customer to require that certified foundry records concerning the material thus produced be filed with him by the manufacturer.

Steel pipe and protective coatings. Committee work in the field of specifications for steel pipe and protective coatings continues under the leadership of H. Arthur Price and with the cooperation of the Steel Water Pipe Manufacturers Technical Advisory Committee. Several items under the jurisdiction of this committee are in

process of revision; no documents have been published during the year. The committee has prepared standard dimensions for steel water pipe fittings, which have been approved and are tentatively scheduled for publication in the April 1956 issue of the JOURNAL.

The Association, as well as its Committee on Steel Pipe and Protective Coatings, is frequently called upon to consider the applicability of asphaltic-base coatings to steel water pipe as an alternate to the tar enamel coatings which are now included in the Association's specifications. The committee recognizes that asphaltic-base coatings are used for external pipe protection in the oil and gas industry. The committee does not, however, consider that asphaltic enamels presently available are suitable for internal coat ing of steel water pipe.

Reinforced concrete pipe. Specifications C301 (Reinforced Concrete Pipe, Steel Cylinder Type, Prestressed) were revised to include the production of the type of pipe colloquially called "imbedded-cylinder" reinforced concrete pipe. The committee has in hand at the present time the preparation of a manual on installation of reinforced concrete pipe, but completion is not promised during 1956.

Asbestos-cement pipe. Specifications for asbestos-cement pipe (C400) remain in "Tentative" status.

Valves and hydrants. Specifications for California type (wet-barrel) hydrants have been prepared by a special task group of the California Section, edited by the AWWA Secretary, and returned to the California Section task group for consideration.

Specifications for metal-seated butterfiy valves (C505) were prepared for publication in the February 1956 JOURNAL [which also carried a summary of the revisions to the rubber-seated butterfly valve specifications, C504]. Separate reprints of C505 and of C504, as revised (including a section on pneumatic operators), will shortly be available for purchase.

Pipelines. C600, Specifications for Installation of Cast Iron Water Mains, has had added to it a section on mechanical-joint pipe [published in the January 1955 JOURNAL]. The revised document is available as a separate reprint.

Meters. The Committee on Meters was very sharply reactivated by Chairman James G. Carns Jr. during 1955. In addition to the revision of several of the existing standards, the committee is working on a proposed test procedure for water meters and, at longer range, on the preparation of a meter manual. Both of these operations are important and will be a credit to the Association and the committee.

Water storage tanks. The committee under the chairmanship of H. O. Hill has just completed a series of extensive revisions to the present specifications, which have been approved and scheduled for publication [published in reprint form in February 1956].

Deep well vertical turbine pumps. A committee operating under ASA procedure, with P. H. Brown and M. H. Owen as cochairmen, completed its original (1949) assignment during 1954. The document passed through the routine of approval within AWWA and ASA. It was approved as an ASA standard by the American Standards Association on May 11, 1955 [published in July 1955 JOURNAL as ASA B58.1 and AWWA A101].

During the time that the committee was at work, it included fourteen members of AWWA, plus representatives from seven other associations. The

Vertical Turbine Pump Manufacturers Association also participated, through its duly appointed representative, Clark Bower. After the document was approved by ASA, however, the Vertical Turbine Pump Manufacturers Association filed a communication withdrawing its connection with the project and refusing to be listed as a participant. It should be noted that this withdrawal derived from the fact that the committee had established a nominal length of 10 ft for discharge column pipe, which does not coincide with the existing commercial practices of some of the pump companies. Therefore, the entire group (as an association) withdrew.

Division Task Groups

Water Resources Division. This Division has established five task groups—Weather Control; Production of Usable Water From Salt Water; Watershed Protection and Erosion Control; Artificial Ground Water Recharge; and Underground Waste Disposal and Control. None of these task groups filed a report during 1955.

Water Purification Division. The Division has appointed eight working task groups:

1. *Fluoridation Materials and Methods.* The task group filed an annual report and census of fluoridation (to Dec. 31, 1954), which was published in the December 1955 JOURNAL.

2. *Instrumentation and Methods of Testing Radioactive Contamination in Water.* The task group has made a survey of the readiness of state and water utility laboratories to detect such contamination. The survey was reported during the Nuclear Engineering and Science Congress in December 1955 and will be published in the JOURNAL.

3. *Molecular Filter Membranes.* The task group made no report during 1955 but proposes to renew its activities because of certain recent developments in this field.

4. *Survey of State Regulations on Water Treatment Plant Design.* The task group has not made a report. A special task group has been appointed by this Division to parallel the activities of similar task groups in the other three Divisions. Each of these task groups has assigned to it a study of the *Manual of Water Works Design* which has been issued by the state sanitary engineers of ten states bordering the Great Lakes. Reports of all of these Division task groups are scheduled for presentation during the St. Louis Conference.

5. *Synthetic Detergents.* The task group made a substantial contribution to the literature of the field during 1955 [published in the January 1956 JOURNAL].

6. *Biological Infestation of Purified Water.* The task group conducted a symposium during the Chicago Conference. The statements made at this symposium are scheduled for publication in the JOURNAL [*this issue,* p. 258].

7. *Manganese Deposition in Pipelines.* The task group has been provided with an extensive bibliography of articles on manganese problems, but has not as yet made a report of any nature.

8. *Cold-Water Corrosion of Copper Tubing (Internal).* The task group has made no report concerning its activities.

Water Distribution Division. A research project at the University of Illinois on the effect of purification methods on water main carrying capacities continues under a National Institutes of Health grant. A report covering

the first year's work on this study was published in the November 1955 JOURNAL. There is good reason to believe that some fairly definite statements may be available from T. E. Larson, who is conducting the research, during 1956.

The Task Group on the Study of Breaks in Water Distribution Systems, through the chairman, H. E. Jordan, has been responsible for the publication in the JOURNAL during 1955 of papers on this subject by L. V. Garrity, H. W. Niemeyer, F. E. Dolson, M. J. Shelton, and W. D. Hurst. The practice of encouraging the publication of records of carefully conducted studies of the causes of breaks in water distribution lines will be continued.

A new working committee has been set up to study allowances for water hammer in various types of water distribution pipe. This group was organized under the chairmanship of S. L. Kerr and includes W. H. Cates, S. M. Clarke, F. G. Gordon, K. R. Kennison, A. J. Maahs, J. T. MacKenzie, and M. K. Socha. Chairman Kerr, in his letter accepting the position, said, in part:

> A standard allowance for water hammer becomes both unsafe and uneconomical for high velocities and for large diameters of any type of pipe. It is my feeling that standard allowances may be desirable for distribution systems, but, for large-diameter transmission systems or for pump discharge lines, I do not believe they are the proper solution.
>
> It is my feeling that the "design philosophy" of various types of water mains should be examined and set forth in simple language. It may well be that standard allowances could be used for almost any type of pipe in distribution systems where the diameter is less than 24 in.
>
> Where the diameters are over 24 in., the cost of pipe becomes a substantial factor and the investment warrants the cost of detailed water hammer studies or engineering investigations. The use of remedial devices to limit water hammer to the design value becomes increasingly justified as the diameter of the conduit increases and its length increases.

The task group had a meeting in Chicago in November, with the chairman of the Committee on Water Works Practice in attendance. A preliminary report by this important task group is expected at the St. Louis Conference.

Management Division. Task groups of the Management Division all operate under the jurisdiction of the Committee on Water Works Administration.

Joint Committees

Standard Methods for the Examination of Water, Sewage, and Industrial Wastes appeared in its tenth edition in April 1955, under the sponsorship of APHA, AWWA, and FSIWA. The committtee for the preparation of the eleventh edition is now a joint editorial board, with F. M. Gilcreas representing APHA, Michael J. Taras representing AWWA, and Gail P. Edwards representing FSIWA. The eleventh edition is not expected to be published before 1960.

Uniformity of methods of water examination. The establishment of a Joint Committee on Uniformity of Methods of Water Examination is being discussed. It is proposed to operate under the sponsorship of eleven organizations which now issue methods for water examination.

Backflow preventers. The joint committee of AWWA and the Conference of State Sanitary Engineers on backflow preventers has prepared a final report which is now being circulated among the approval bodies prior to publication. The document is an extensive one and contains material of somewhat controversial nature.

Publication may be delayed longer than would normally be the case because of the nature of the study.

Chlorine supplies. The joint committee on Chlorine Supplies has been relatively inactive during 1955.

Filtration manual. The Joint Committee on Revision of ASCE Manual on Filtration of Water is now fully organized under the chairmanship of R. L. Derby. The following individuals have been appointed as representatives of AWWA: W. W. Aultman, J. R. Baylis, H. A. Faber, P. D. Haney, H. O. Hartung, Richard Hazen, J. E. Kerslake, H. E. Lordley, R. L. McNamee, and J. M. Montgomery. The following represent ASCE: J. J. Baffa, C. A. Black, K. W. Cosens, R. C. Kenmir, J. E. McKee, R. C. Merz, T. M. Niles, G. R. Scott, C. H. Spaulding, and H. L. Thompson.

Spillway design capacities. The Joint Committee on Spillway Design Capacities is now officially organized under the chairmanship of Thomas H. Wiggin. Representing AWWA on the committee are R. E. Oltman, of the US Geological Survey, and Karl R. Kennison, Chief Engineer, Board of Water Supply, New York City. Representing ASCE are F. B. Slichter, US Army Corps of Engineers, Washington, D.C., and C. J. Posey, Head, Civil Engineering Department, University of Iowa, Iowa City. The first meeting of the committee was held in New York in October 1955 on the occasion of the annual meeting of ASCE.

Oil line river crossings. Since the Chicago Conference negotiations have been carried on with the American Petroleum Institute looking toward the establishment of a joint committee to consider the problems of oil line crossings involving water supplies, watersheds, and rivers. The following representatives have been appointed: For API—R. K. Paine, Standard Oil Company of California; C. C. Keane, Great Lakes Pipe Line Company, Kansas City; R. H. Lynch, Keystone Pipe Line Company, Philadelphia; and L. F. Scherer, Texas Pipe Line Company, Houston. For AWWA—M. B. Cunningham, E. L. Filby, and V. C. Lischer.

Committees of Other Organizations

Technical Advisory Board for Research on Decontamination of Radioactive Waters. This joint board, established by the Atomic Energy Commission and the US Public Health Service, on which Secretary Jordan represents AWWA, has not been called upon for any meeting during 1955, nor has there been any indication that the work of the joint board is considered complete. This inactivity would appear to derive from the administrative confusion originating in Washington with the Atomic Energy Commission, which represents certain viewpoints in Congress, and the Joint Congressional Committee on Atomic Energy, which represents other viewpoints.

Task Group to Develop a Manual on Security Principles for the Water Works Industry. This US Public Health Service project, on which R. J. Faust represented AWWA, has been informally liquidated. Faust has been requested by the Public Health Service to act as a special consultant to the service, with the intimation that such demands as are made on his time will relate to water works security.

Joint Committee for the Advancement of Sanitary Engineering. This committee has now been reorganized as the American Sanitary Engineering Inter-Society Board. R. J. Faust, W. R. LaDue, and R. E. Stiemke represent AWWA.

Engineers Joint Council. Through the activities of R. J. Faust and Noel S. Chamberlin, AWWA scheduled fifteen papers at the December 1955 EJC congress on nuclear energy. All of the papers presented were issued in preprint form. Some of the material scheduled by AWWA will be published in *Willing Water* or the JOURNAL. [A list of the AWWA-sponsored papers appeared in the "Coming Meetings" section of the November and December 1955 JOURNAL, p. 8 P&R.]

ASA Committees

A13—Scheme for Identification of Piping Systems. The draft of the final report of this committee, circulated in 1954, received a number of negative votes. The document has not yet been submitted for approval.

B2.1—Pipe Threads. No action of this committee was recorded in 1955.

B16—Pipe Flanges and Fittings. A proposal is before the ASA to except from the scope of the activities of Committee B16 the standards developed by ASA Committee A21 and the various specifications of AWWA on steel pipe and fittings, gate valves, fire hydrants, sluice gates, and butterfly valves for water distribution.

B31—Code for Pressure Piping. S. L. Kerr, who was representing the Association on this important committee, has terminated his participation in its activities. He recommends the appointment of Thomas F. Wolfe to represent AWWA on this committee. (Wolfe already represents the Cast Iron Pipe Research Association and the New England Water Works Association in the activities of the committee and is thoroughly familiar with the nature of the work it does.) [The Board approved the appointment.]

K61—Storage and Handling of Anhydrous Ammonia and Ammonia Solutions. R. J. Faust represents AWWA. The committee is presently considering the draft of its final report.

Y1—Standardization of Abbreviations. This committee includes Eric F. Johnson as AWWA representative. The fourth draft of the Proposed American Standard Abbreviations for Use in Text has been circulated among members of the committee. The draft was criticized both in correspondence and at a meeting of the committee on Nov. 28, 1955, and is now in the hands of the subcommittee for further revision. Meanwhile the Subcommittee on Abbreviations for Use in Drawings is being activated to work with the text subcommittee in recommending methods by which the two sets of abbreviations can be combined into a single document.

Other ASA committees on which AWWA is represented have developed no material during the year which merits reference in this report.

A12—Dimensional Standardization of Plumbing Equipment (Proposed). AWWA has notified ASA that it desires to be represented on this proposed committee, in order to protect the present AWWA standards for service line fittings. It is suggested that J. W. Bradbury, technical advisor to AWWA on these standards and also its representative on ASA Committee B2 (Screw Threads), be designated AWWA representative. [The Board approved the appointment.]

ASA is presently organizing a general committee on standardization in the field of nuclear energy. ASA has been advised that AWWA wishes to be represented on the committee. For the time being, until the extent and scope of the activities are more clearly defined, it is recommended that Secretary Jordan be appointed AWWA representative. [The Board approved.]

Report on Publications

For the Year Ending December 31, 1955

A report on the publishing activities of the Association for the year ending Dec. 31, 1955, submitted to the AWWA Board of Directors on Jan. 17, 1956, by Eric F. Johnson, Asst. Secretary—Publications.

BECAUSE of the disruption caused by three personnel changes on the editorial staff of the JOURNAL, 1955 was rather a "scrambling" year, not only for the JOURNAL itself, but for some of the other publications as well, with a number of rather late appearances and one actual postponement. Nevertheless, the year was certainly one of considerable accomplishment. Economically, it set more new records —in advertising income again, as well as in sales of books and manuals. And during the year the long-awaited tenth edition of *Standard Methods* was issued, the public relations manual, *Silent Service Is Not Enough!,* appeared, and the new safety manual was introduced in a six-installment presentation in the JOURNAL (July–December).

1. The Journal

A detailed picture of JOURNAL contents, costs, and income for the years 1951–55 is presented in Table 1.

a. Contents. Although the number of articles printed in the JOURNAL in 1955 was exactly the same as in 1954, the number of pages devoted to those articles was reduced by more than 100, representing an average reduction in length of almost a page per article. Unfortunately, this reduction cannot be credited either to a trend toward conciseness or to more thorough editing, but is merely the result of an effort to print a maximum number of papers from the large selection available and worthy of publication. The fact that fewer words were printed despite the oversupply of material must be charged to the reduced effectiveness of a staff which suffered two changes in the key position of manuscript editor during the year. Even at best, though, the present staff could not have handled much more than another 100 pages, and that would have made very little difference in the overall picture of much more worthy material than space for it.

The reduction in total JOURNAL pages for the year was only 80 because of another increase in the size of the advertising section. And even though that increase was, by economies in makeup, held well below what might have been expected from a growth of 43 pages in total paid advertising, the advertising section once more surpassed the text section in size. Of itself, the largeness of the former is hardly something to complain about, indicating as it does the robust economic health of the JOURNAL. But efforts to keep it more or less in balance with the text section have, in the past few years, reduced the space available for the "Percolation and Runoff" section, the abstracts, and other similar features, to a point where this portion of the JOURNAL, too, has felt the squeeze of more material than space.

TABLE 1

Journal Contents, Costs, and Income, 1951–55

Item	1951	1952	1953	1954	1955
Contents					
Text pages	1,076	1,218	1,378	1,366	1,262
Advertising pages	1,340	1,390	1,182	1,258	1,282
Total pages	2,416	2,608	2,560	2,624	2,544
Text articles					
Conference papers	32	28	21	24	23
Section papers	44	68	61	67	90
Contributions	20	25	24	36	19
Reports & official documents	22	24	33	18	13
Total articles	118	145	139	145	145
Abstract pages*	94	108	85	75	72
Costs†					
Production	$ 3,706	$ 5,187	$ 4,921	$ 4,598	$ 5,303
Printing	37,234	42,521	47,036	46,182	47,217
Paper	10,742	13,876	14,088	15,207	15,232
Total Costs	$51,682	$61,584	$66,045	$65,987	$67,752
Total-cost Index‡	105.5	125.7	134.8	134.7	138.4
Cost per copy	42.5¢	45.9¢	47.5¢	46.7¢	45.9¢
Cost per 1,000 pages	$ 2.07	$ 2.07	$ 2.19	$ 2.09	$ 2.13
Printing rate index‡	107.9	107.9	113.3	115.5	115.5
Paper rate index‡	111.4	118.2	118.2	120.6	123.1
Income					
Advertising	$72,639	$85,147	$85,076	$100,951	$107,209
Subscriptions	$ 6,797	$ 7,094	$ 7,510	$ 8,943	$ 9,172†
Total pages paid advertising	847	879	856	926	969
Advertising rate index‡	100	113.3	113.3	124.0	124.0
Cost per 1,000 circulation	$ 8.25	$ 8.73	$ 8.30	$ 8.70	$ 8.17
Circulation (avg per issue)	9,094	9,740	10,238	10,687	11,385
Circulation index‡	106.8	114.4	120.2	125.5	133.7

* On basis of present format.
† At variance with audit figures because of different basis.
‡ 1950 = 100.

b. Cost and Income. The cost figures reported are unexceptional, showing a slight increase over the 1954 totals, attributable primarily to an increase in paper prices and an increase in the number of copies printed. Actually, reflecting the reduction in the size of issues as well as the greater circulation, average cost per copy went down and cost totals throughout were proportionately below the budget. Meanwhile, income again exceeded ex-

pectations, advertising income running 6 per cent above the $101,000 record of 1954.

c. The future. The pressing problem of space—space for more technical articles, for more news of sections and members, for more book reviews, for more abstracts—has made the staff more anxious than ever to explore the possibility of splitting the JOURNAL into two publications. But the present problem—particularly that of reducing the backlog of accepted manuscripts—is too acute to wait for any such long-term development. At the end of the year, 29 Chicago Conference papers were still on hand awaiting publication, as were 17 section meeting papers, 20 contributions, and 3 specifications and reports. Altogether, the definitely scheduled material was enough to fill every issue through June 1956, and yet to be considered for publication were more than 80 papers from the fall 1955 section meetings, not to mention those that will be forthcoming before June from the spring 1956 section meetings and the St. Louis Conference. In recognition of the fact that even the "must" material involved will require considerably more space than would be available in the JOURNAL under 1955 space limitations, the only solution that will permit reasonable coverage of experience and progress in the field seems to be an immediate increase in the size of the JOURNAL.

As far as direct expenses are concerned, an increase in JOURNAL space in 1956 seems quite feasible. It is felt that by adding 432 pages to the 1955 size—thereby making available the equivalent in text of almost four more issues—the present pressure can be considerably relieved. Such an increase would involve the expenditure of an additional $9,500 during the year, running the overall JOURNAL budget up to $80,000. Offsetting most, if not all, of the additional expense will be the additional income derived from the advertising rate increase of approximately 7 per cent that was put into effect as of January 1956. Conservative estimates indicate that the spread between direct JOURNAL expense and advertising income (see Table 2) will suffer a significant drop in the process, but in percentage spread, the 40 per cent indicated for 1956 would compare favorably with those of all but 2 of the last 5 years.

TABLE 2

Relation of Journal Cost to Advertising Income, 1951–55

Year	Total Cost $	Advertising Income $	Dollar Spread $	Percentage Spread %
1951	51,682	72,639	20,957	40.5
1952	61,584	85,147	23,563	38.3
1953	66,045	85,076	19,031	28.8
1954	65,987	100,951	34,964	53.0
1955	67,752	107,209	39,457	58.2
1956*	80,000	112,500	32,500	40.6

* Budget figures.

As far as personnel is concerned, however, the increase in size will not be feasible until more help is made available. A little less than 100 per cent effective last year because of personnel changes, the staff nevertheless operated close enough to capacity to indicate that adding 400 text pages to its load would mean giving it approximately 25 per cent more text than it could handle.

The tremendous growth of the Association, as well as the recent acceleration of activity and progress in the water works field, has given the JOURNAL a much bigger job of providing

reasonable coverage of current practice and progress. The financial status of the JOURNAL will support its doing that bigger job, but the present personnel is not adequate to handle it. Although the scheduling of 400 additional pages of technical articles would not, of itself, provide enough work to keep another editor busy full time, there is more than enough other work to fill out the job—the abstracts section has been fading away for lack of staff time, the work on the *Directory* has been getting further and further out of hand as both membership and services have grown, the production work on *Willing Water* has been getting further and further behind, and the load of promotion and sales work required on a larger and larger list of publications has been increasing. With both additional pages and additional help so clearly needed, provision has been made in the proposed 1956 budget for both the additional expenditure required and the additional salary involved, so that, by approving the budget, the Board will make possible these adjustments to progress. [The Board approved.]

TABLE 3

Comparative Data on Directory *Reference Editions, 1953–55*

Item	1953	1955
Total pages	136	176
Number of copies printed	12,330	13,990
Total cost	$4,416	$5,893
Cost per 1,000 pages	$2.56	$2.34
Cost per copy	35.8¢	42.1¢
Total pages paid advertising	44	57
Advertising income	$3,841	$6,266
Net cost per copy	4.7¢	−2.7¢

Once the staff is a little more on an even keel, it is hoped, too, to pursue more intensively the development of a definite plan for converting *Willing Water* into a second full-scale publication of the Association to handle not only public relations articles, but other relatively nontechnical and timely material, leaving for the present JOURNAL the more scholarly articles which have a permanent reference value.

d. Offprints. As a footnote to the discussion of the JOURNAL, it should be reported that the provision of 50 free "offprint" reprints of each JOURNAL paper to authors, as authorized by the Board in the 1955 meeting, was put into effect with the March 1955 issue. A separate record of the cost of the operation (included in the production cost figure in Table 1) has shown it to be well within the estimated cost—$470 compared with the budgeted $600 for the ten months of 1955. Reprint sales, meanwhile, were not significantly affected, the total for 1955 falling only $70 short of the $5,765 of 1954.

2. The Directory

The 1955 *Directory* will be remembered as the first in which advertising income exceeded direct costs (see Table 3). This turn of the tide, of course, came with the "small" edition—that is, the Reference Edition—but it was nevertheless most gratifying, for it required a boost of 63 per cent in advertising income to accomplish the feat in the face of increasing cost and size. The increased cost resulted from a combination of higher printing and paper prices and the rise in number of copies printed. The increased size

resulted from the addition of the "Directory of Committees" and from the growth of other features, including, of course, the advertising section. At 176 pages, compared with the 256 pages of the last two Membership List Editions, this portion of the *Directory* now includes all the features which were originally scheduled for it in the splitup of the biennial edition in 1952.

One of the offshoots of the Reference Edition that has been particularly valuable to the staff in supplying information has been the reprinting of the "Buyers' Guide" and the "Directory of Consultants" as separate booklets, and the fact that these separate reprints contain the advertising of the Associate Members and the consultants is, of course, a helpful sales point in advertising promotion.

The 1956 *Directory* will be the larger and more costly Membership List Edition, which is budgeted at $11,000, almost twice the cost of the 1955 *Directory*, and is thus unlikely to maintain the favorable cost-income relationship. As a matter of fact, advertising income has been conservatively estimated at $6,000, indicating a net cost of approximately 33 cents per copy rather than the − 2.7 cents of the 1955 book.

3. Specifications

Fewer specifications were completed during 1955 than in most recent years. Only those for deep well vertical pumps (A101) and liquid sodium silicate (B404) and the mechanical-joint addendum to the cast-iron main installation specifications were published in the JOURNAL and made available in reprint form during the year. Yet overall sales of specifications increased 23 per cent, from $9,600 to $11,800—a particularly good indication of the growing acceptance and use of AWWA standards throughout the field.

4. Journal Indexes

Sales of the 1881–1939 index totaled only 13 during the year, leaving 107 copies in stock to fill future orders for this volume. Meanwhile the 1940–54 index, which was expected to issue during the year, suffered the consequences of the same changes in personnel that disrupted JOURNAL schedules. By the end of the year, however, the main classification job had been completed and publication of an index to include 1955 as well was scheduled for midyear 1956. Preliminary bids on the basis of a clothbound volume of 200 pages or slightly more indicate a probable list price of $2.50. To allow for the printing of 3,500 copies and the immediate binding of 1,500–2,000, a budget of $4,000 has been set.

5. Willing Water

Although December 1955 had to be stretched a good bit to make it possible, *Willing Water* did manage to complete another year as an eight-page bimonthly. Actually, the difficulty has been lack of time rather than lack of material, and it is planned to continue the bulletin on the same schedule in 1956. Covering safety, water resources, and education, as well as direct public relations, during 1955, *Willing Water* has been found a particularly useful medium for bringing current programs and issues to the attention of the field.

In 1955 publication and mailing costs were again held below $5,000. In the expectation of price increases in paper, envelopes, and printing, and with the possibility of a more elaborate "75th Anniversary" issue, the budget re-

quest for 1956 has been continued at $6,000.

Sales of "public relations material"—that is, Willing Water newspaper mats and electrotypes, posters, postal meter slugs, decals, and reprints—and of the Willing Water jewelry novelties showed a healthy profit during the year, more than repaying the investments of 1954. Both these items continue as small-scale operations primarily because no direct promotional effort has been made recently. They continue, however, to be a helpful sidelight in the public relations program.

TABLE 4

Summary Data on Public Relations Booklets

Booklet	No. Printed	No. Sold	Inventory	Production & Sales Expense $	Income $	Inventory Value $
Story of Water Supply	800,000	624,750	175,250	20,322.61	30,264.63	2,996.78
Your Water Supply	659,640	624,140	35,500	10,061.31	15,833.07	461.50

6. Booklets

Although a little less spectacular than in 1954, sales of both public relations booklets held up remarkably well, the totals reaching 225,000 copies for *The Story of Water Supply* and 100,000 copies for *Your Water Supply*. A summary of the sales, income, and cost figures for the 2 years that the booklets have been in print is presented in Table 4.

a. The Story of Water Supply. During 1955, two 200,000-copy printings of *The Story of Water Supply* were required. As the second was completed in November, however, most of that lot was on hand at the end of the year. During the year the only full-scale promotion was the distribution of sample copies to all members with the February 1955 issue of *Willing Water*, but form follow-up letters have been sent to water utilities in all communities from which teacher or school inquiries about the booklet were received—and these inquiries numbered well into the hundreds as a result of favorable reviews of the booklet and its accompanying teacher's manual in a number of the education magazines. With the thought of getting more utilities to offer the booklets to their local schools, another general promotional mailing of samples is scheduled for 1956.

b. Your Water Supply. Getting along strictly on repeat sales and word-of-mouth promotion during 1955, *Your Water Supply* had a really really remarkable record. Although it, like *The Story of Water Supply*, has already sold well over 600,000 copies, the potential is estimated at well over a million. At the earliest opportunity, therefore, these booklets, too, will be given further promotion.

c. What Price Water? As the next booklet in AWWA's series, it is hoped to convert the 1950 *What Price Water?* into bill stuffer size and to make it available to utilities that are promoting rate increases. It is expected that this job can be at least initiated during 1956.

7. Books

A consolidated summary of financial data on the four books now being actively promoted and sold directly by AWWA is presented in Table 5. As will be noted, all but *The Quest* are well beyond the break-even mark in sales, and that philanthropically financed venture, too, will pay for itself in another 3–4 years if just the remaining bound copies can be sold. What seems rather remarkable is the continued response elicited by promotional mailings. In 1955, again, an advertisement sent along with an issue of *Willing Water* boosted sales to the point where every one of the books sold more copies than in the preceding year.

A review of 1955 activity of each of the books and of *Standard Methods*, the distribution of which is handled by the American Public Health Association, follows:

a. Manual of Water Works Accounting. Sales: 121 copies in 1955; 84 in 1954; 32 in 1953.

b. Survival and Retirement Experience With Water Works Facilities. Sales: 103 copies in 1955; 68 in 1954; 51 in 1953. The demand for this volume necessitated binding an additional 250 copies during the year.

c. The Quest for Pure Water. Sales: 84 copies in 1955; 77 in 1954; 52 in 1953.

d. Water Quality and Treatment. Sales: 544 copies in 1955; 539 in 1954; 425 in 1953. With only 211 bound copies on hand at the end of the year, a new binding of 500 copies is now under way.

During the year revisions of the sedimentation and aeration chapters of *Water Quality and Treatment* were published in the JOURNAL (August and September). A combined reprint of these two chapters, available in February 1956, will be distributed free with each copy of the book sold on or after Sep. 1, 1955. During 1956 the revised chapter on filtration, last of the revisions in prospect, will be published in the JOURNAL, after which reprints of that, too, will be provided to all subsequent purchasers of the book. So that earlier purchasers will also be able to keep copies of the new chapters on file with the original volume, the reprints will also be made available for general sale at usual reprint prices.

e. Standard Methods for the Examination of Water, Sewage, and Industrial Wastes. The long-awaited tenth edition finally appeared at the beginning of April 1955 and in the last 9 months of the year sold more than 8,000 copies, promising to overshadow even the record of the ninth edition, which totaled 22,000 copies in its 9-year life.

Looking forward to the eleventh edition now, the three societies (APHA, FSIWA, and AWWA) made their appointments to the Joint Editorial Board, which had its first meeting in Atlantic City in October 1955 to develop preliminary plans for reviewing and revising current methods, with the possibility of issuing a supplement to the tenth edition before a complete revision of the book becomes necessary. Michael J. Taras is the AWWA representative on the Joint Editorial Board, as well as the chairman of the AWWA *Standard Methods* Committee. In the latter capacity, too, he has been busy reorganizing the various tenth-edition subcommittees to prepare them for a watchdog job in the 5 years or more before a new edition will be required.

TABLE 5

Summary Data on Current AWWA Books and Manuals

Year Published	Book	No. Printed	No. Bound	No. Sold	Inventory		Production & Sales Expense $	Income $	Value of Inventory on Hand $
					Bound	Unbound			
1938	*Manual of Accounting*	1,898	1,898	1,535	363		3,351.57	5,416.71	540.87
1946	*Survival and Retirement*	3,006	2,254	2,069	185	745	4,822.71	5,934.77	965.33
1948	*Quest for Pure Water*	2,512	2,021	1,676	345	491	8,660.99	7,194.93	1,189.67
1950	*Water Quality and Treatment* (2nd edition)	9,300	4,500	4,289	211	4,800	13,705.86	18,636.25	2,716.50
	Manual								
1954	*Water Rates Manual*	1,000	1,000	688	312		623.14	668.90	145.05
1955	*Silent Service Is Not Enough!*	5,038	2,538	312	2,226	2,500	956.62*	281.22	851.92

* Includes $294.97 charged to 1954 JOURNAL paper.

8. Manuals

As will be noted from the financial summary of the two manuals now in print (included in Table 5), one has already turned the break-even corner, whereas the other is just getting under way. A review of their 1955 activity follows:

a. Water Rates Manual. Through inclusion in the promotional mailing, sales in 1955 were boosted to 478 copies, compared to the 210 copies in 1954. With only 312 copies now in stock, a new printing is scheduled for 1956.

b. Silent Service Is Not Enough! Issued in April 1955, this manual includes the public relations text published in the December 1954 JOURNAL, plus an appendix of facts, statistics, and ideas for use by water works speakers. A total of 5,000 copies of the text was printed, 2,500 copies being bound with the appendix and the other half being held for later binding with an appendix then revised to bring it up to date. A total of 312 copies was sold during the year.

c. Safety Manual. As approved by the Board in January 1955, the *Safety Manual* was published in the JOURNAL in six installments, running from July through December. The combined 128-page manual is scheduled for issuance in March 1956 in a first printing of 2,000 copies that will be sold at a list price of $1.50 per copy, with the usual 20 per cent cash discount to members. The type for this manual has been purchased so that it can be reprinted as often as demand indicates.

d. Other manuals in prospect. A manual covering meter installation and maintenance practices has already been undertaken by the meter committee as the next addition to this list. Proposed, too, are six short-course manuals, which will logically fit into this publication series.

Report of the Audit of Association Funds

For the Year Ending December 31, 1955

To the Members of the American Water Works Association:

The By-Laws require that the Secretary have an audit made annually of the books of the Association.

The records for 1955 have been examined by the staff of Louis D. Blum & Co. The complete record of that examination follows.

Audits have been published in the JOURNAL annually. Since 1942 they have appeared in the March issue.

Respectfully submitted,
HARRY E. JORDAN
Secretary

January 23, 1956

TO THE AMERICAN WATER WORKS ASSOCIATION:

We have examined the balance sheet of the American Water Works Association as of December 31, 1955, and the related statements of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet as of December 31, 1955, and the related statements of income and surplus present fairly the financial position of the American Water Works Association at that date and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

(Signed)
LOUIS D. BLUM & CO.
Certified Public Accountants

EXHIBIT A—Balance Sheet

December 31, 1955

Assets

Cash in Banks and on Hand		$ 41,925.40
Accounts Receivable:		
Membership Dues	$ 533.85	
Advertising—Journal	7,226.88	
Reprints	494.99	
Sundry specifications	766.32	
Your Water Supply (booklet)	452.61	
The Story of Water Supply (booklet)	825.01	
Other	297.23	10,596.89
Accrued Interest on Bonds		840.62
Inventories:		
Paper stock	11,423.16	
Type metal	2,506.57	
Water Quality and Treatment (book)	2,716.50	
Manual of Water Works Accounting (book)	540.87	
Water Rates Manual (manual)	145.05	
Sundry specifications	2,566.29	
Quest for Pure Water (book)	1,189.67	
Survival and Retirement (book)	965.33	
Willing Water novelties	35.90	
Cumulative Index	128.40	
Your Water Supply (booklet)	461.50	
The Story of Water Supply (booklet)	2,996.78	
Silent Service Is Not Enough! (manual)	851.92	
Back Issues—Journals—Vol. 1–47, inclusive (50,095 copies)	—*	
Back Issues—Proceedings—1881–1913, inclusive (245 copies)	—*	26,527.94
Office Equipment (less depreciation)		8,941.54
Investments at Cost (Schedule 1)		183,227.80
Deferred Expenses		4,129.85
Deposit—Airlines		425.00
Total Assets		$276,615.04

Liabilities and Surplus

Accounts Payable	$ 455.47
Membership Dues—Advance Payments	60,691.82
Unearned Subscriptions to Journal	5,107.52
Unearned Advertising—Directory	1,560.00
Payable to American Water Works Association Pension System	20,000.00†
Reserve for Award Fund (McCord)	53.02
Senior Members Contributory Fund	2,529.05
Surplus, per Exhibit C	186,218.16
Total Liabilities and Surplus	$276,615.04

* Back issues of Journals and Proceedings are inventoried but no money values are assigned to them for balance sheet purposes inasmuch as the entire costs were charged off during the year of publication. The quantity shown is in accordance with a tabulation supplied by the Association's printer.

† Secured by the assignment of the income of US Savings Bonds, Series G, and maturity redemption value of such bonds in the amount of $20,000.00.

EXHIBIT A, Schedule 1—Investments
December 31, 1955

Description	Interest Rate %	Principal Amount	Cost	Quoted Market or Redemption Value Dec. 31, 1955
Foreign Securities:				
Province of Ontario	4	$ 1,000.00	$ 732.50	$ 1,040.00*
Dominion of Canada, 6th Victory Loan	3	2,000.00	2,000.00	1,965.00†
Hydro Electric Power Commission of Ontario	2.75	5,000.00	5,075.00	4,537.50†
Province of Ontario	3	2,000.00	2,022.50	1,895.00†
Hydro Electric Power Commission of Ontario	3	2,000.00	2,020.00	1,885.00†
Dominion of Canada, 9th Victory Loan	3	5,000.00	4,775.00	4,862.50†
United States Securities:				
US Savings Bonds, Series:				
G	2.5	10,000.00	10,000.00	9,860.00‡§
G	2.5	10,000.00	10,000.00	9,730.00‡§
G	2.5	2,000.00	2,000.00	1,972.00‡
G	2.5	10,000.00	10,000.00	9,820.00‡
G	2.5	3,000.00	3,000.00	2,937.00‡
G	2.5	10,000.00	10,000.00	9,730.00‡
G	2.5	2,000.00	2,000.00	1,946.00‡
G	2.5	5,000.00	5,000.00	4,850.00‡
G	2.5	2,000.00	2,000.00	1,940.00‡
G	2.5	7,500.00	7,500.00	7,207.50‡
G	2.5	2,500.00	2,500.00	2,372.50‡
G	2.5	1,000.00	1,000.00	947.00‡
K	2.76	5,000.00	5,000.00	4,875.00‡
K	2.76	2,000.00	2,000.00	1,970.00‡
K	2.76	20,000.00	20,000.00	19,700.00‡
K	2.76	5,000.00	5,000.00	4,925.00‡
K	2.76	10,000.00	10,000.00	9,920.00‡
US Treasury Bills		60,000.00	59,602.80	59,672.40
		$184,000.00	$183,227.80‖	$180,559.40‖

* This security is payable in United States funds.
† These securities are payable in Canadian funds. Market value represents value in New York in United States funds.
‡ These amounts represent redemption value on Dec. 31, 1955.
§ Redemption value and income of these securities assigned to American Water Works Association Pension System.
‖ In addition to the above, the Association owns 1 share of Seymour Water Co. 6 per cent preferred stock, par value $25. This share of stock was received as a contribution in a prior year.

EXHIBIT B—Statement of Income and Expenses
For the Year Ended December 31, 1955

Operating Income:

Annual dues	$116,405.92	
Advertising—Journal	107,143.00	
Advertising—Directory	6,265.75	
Subscriptions to Journal	9,555.64	
Convention—registration fees	30,295.00	
Convention—ticket sales	3,489.50	
Convention—other events	343.00	
Water and Sewage Works Manufacturers Assn.	7,500.00	
Interest and dividends on investments	3,096.28	
Miscellaneous income	75.30	
Total Operating Income (carried forward)		$284,169.39

TOTAL OPERATING INCOME (brought forward)			$284,169.39
Publication Income:			
Water Quality and Treatment (book)		2,236.49	
One-half of profit from sales of Standard Methods (book)		79.16	
Manual of Water Works Accounting (book)		436.28	
Water Rates Manual (manual)		448.95	
Sundry specifications		12,077.10	
Proceedings and Journals		993.13	
Quest for Pure Water (book)		392.00	
Survival and Retirement (book)		259.00	
Willing Water novelties		300.55	
Reprints		5,888.49	
Silent Service Is Not Enough! (manual)		300.23	
Public relations material		359.68	
Your Water Supply (booklet)		2,573.26	
The Story of Water Supply (booklet)		10,831.63	
What Price Water? (booklet)		4.00	
TOTAL PUBLICATION INCOME			37,179.95
TOTAL INCOME (carried forward)			$321,349.34
Operating Expenses:			
Directors' and Executive Committee Meetings:			
Travel expense	$ 7,103.99		
Stenographic expense	262.40	$ 7,366.39	
Administrative Expenses:			
Rent	10,000.00		
Office supplies and services	13,382.43		
Membership promotion	338.87		
Pension—Secretary Emeritus	2,500.00		
Contributions to pension system	5,688.84		
Legal and accounting expenses	920.34		
General and special travel	2,034.90		
Federal activities	1,729.99	36,595.37	
Administrative Salaries		79,902.07	
Committee Expense		1,875.86	
Division and Section Expenses:			
Section—membership allotment	19,283.59		
Section—travel expense	4,754.60		
Section—general expense	656.09	24,694.28	
Journal:			
Printing	47,311.00		
Production	5,050.17		
Paper	15,287.05		
Abstractors	52.57		
Directory	5,893.33	73,594.12	
OPERATING EXPENSES (carried forward)		$224,028.09	

Total Income (brought forward)			$321,349.34
Operating Expenses (brought forward)		$224,028.09	
Convention:			
General	9,253.29		
Entertainment	16,831.06		
Miscellaneous	299.22	26,383.57	
Membership Dues in Other Associations		1,584.50	
Depreciation of Office Equipment		1,654.98	
Miscellaneous Expenses		1,161.19	
Total Operating Expenses		$254,812.33	
Cost of Publications Sold:			
Water Quality and Treatment (book)	$ 1,145.61		
Standard Methods (book)	235.95		
Manual of Water Works Accounting (book)	262.43		
Water Rates Manual (manual)	7.23		
Sundry specifications	4,020.93		
Proceedings and Journals	88.52		
Quest for Pure Water (book)	229.36		
Survival and Retirement (book)	394.85		
Willing Water novelties	250.32		
Reprints	5,208.29		
Cumulative Index	41.85		
Silent Service Is Not Enough! (manual)	107.03		
Public relations material	274.26		
Your Water Supply (booklet)	1,629.01		
The Story of Water Supply (booklet)	5,238.26	19,133.90	
Development Activities:			
Public relations	4,640.42		
Employment survey	32.70		
Evaluation of fluoride test kits	520.41		
Uniform System of Accounts	2,217.18	7,410.71	
Total Expenses			281,356.94
Net Income for the Year (transferred to Exhibit C)			$ 39,992.40

EXHIBIT C—Surplus for the Year Ended December 31, 1955

Balance, January 1, 1955		$145,034.78
Add: Amounts reimbursed by American Public Health Assn. for moneys expended and written off in a prior year	$ 893.68	
Add: Paper stock used in publication of "Silent Service Is Not Enough!" expensed in a prior year	297.30	
Add: Net income for the year, per Exhibit B	39,992.40	41,183.38
Balance, December 31, 1955, per Exhibit A		$186,218.16

American Water Works Association Pension System

BALANCE SHEET—DECEMBER 31, 1955

Assets

Cash in bank	$ 1,429.51
Accrued bond interest	594.95
Investments (Schedule 1)	98,000.00
TOTAL ASSETS	$100,024.46

Liabilities and Reserve for Future Benefits

Liability for refund of employees' contributions plus earned interest	$ 8,011.72
Reserve for future benefits	92,012.74
TOTAL LIABILITIES AND RESERVE	$100,024.46

STATEMENT OF RECEIPTS AND DISBURSEMENTS FOR THE YEAR 1955

Item	Cash	Reserve for Future Benefits	Liability for Refund of Employees' Contributions
Receipts:			
Association contributions	$ 5,688.84	$ 5,688.84	
Employees' contributions	1,766.41		$1,766.41
Interest on bonds	2,371.20	2,371.20	
Total	9,826.45	8,060.04	1,766.41
Disbursements:			
Investment in Series K bonds	9,000.00		
Refund of contributions plus interest	999.00		999.00
Audit and legal expense	50.00	50.00	
Office expenses	6.60	6.60	
Total	10,055.60	56.60	999.00
Excess of Cash Receipts Over Disbursements	(229.15)*	8,003.44	767.41
Adjustments for Non-Cash Items:			
Interest credited to employees' accounts		(141.52)*	141.52
Interest accrued on bonds, Jan. 1, 1955		(584.25)*†	
Interest accrued on bonds, Dec. 31, 1955		594.95‡	
Total		(130.82)*	141.52
Additions to accounts for year	(229.15)*	7,872.62	908.93
Balance, Jan. 1, 1955	1,658.66	84,140.12	7,102.79
Balance, Dec. 31, 1955	$ 1,429.51	$92,012.74	$8,011.72

* Deduction.
† Accrued interest receivable as per balance sheet Dec. 31, 1954.
‡ Accrued interest receivable as per balance sheet Dec. 31, 1955.

SCHEDULE 1—INVESTMENTS, DECEMBER 31, 1955

Description	Interest Rate %	Principal	Maturity Date
Bonds Registered in Name of Administrative Committee:			
Series G	2.5	$10,000.00*	1961
Series G	2.5	10,000.00*	1962
Series G	2.5	14,000.00*	1963
Series K	2.76	9,000.00*	1964
Series K	2.76	17,000.00*	1965
Series K	2.76	4,000.00*	1966
Series K	2.76	2,000.00*	1966
Series K	2.76	3,000.00*	1966
Series K	2.76	4,000.00*†	1967
Series K	2.76	5,000.00†‡	1967
Bonds Registered in Name of Association and Assigned to Administrative Committee:			
Series G	2.5	10,000.00	1956
Series G	2.5	10,000.00	1958
Total		$98,000.00	

* Redemption value on Dec. 31, 1945: $70,501.00.
† Acquired in 1955.
‡ Not redeemable until Jun. 1, 1956.

1955 Section Membership Awards

Old Oaken Bucket		Hill Cup		Henshaw Cup	
Section	Score*	Section	Score†	Section	Score‡
California	1,266	Southwest	28.665	Cuban	72.2
Southwest	994	Indiana	24.467	Montana	68.4
New York	822	California	19.975	Pacific Northwest	55.0
Canadian	630	Alabama-Mississippi	16.080	Rocky Mountain	55.0
Illinois	527	North Carolina	15.228	Iowa	54.0
Pennsylvania	503	Florida	12.920	North Carolina	50.7
Ohio	445	Pennsylvania	11.808	Ohio	50.0
New Jersey	423	Southeastern	11.408	Wisconsin	49.5
Pacific Northwest	414	Illinois	10.013	Arizona	48.5
Michigan	395	Canadian	7.440	North Central	47.9
Indiana	391	Rocky Mountain	7.096	Indiana	46.9
Florida	336	Virginia	6.728	Alabama-Mississippi	46.6
Southeastern	269	Kansas	6.660	Southeastern	46.4
Chesapeake	248	Nebraska	6.423	Kansas	43.7
North Central	236	Chesapeake	5.900	Nebraska	43.6
New England	224	Kentucky-Tennessee	5.296	Kentucky-Tennessee	42.8
Kansas	222	New York	5.104	Chesapeake	42.2
Alabama-Mississippi	202	Wisconsin	4.764	Michigan	41.3
Missouri	200	Michigan	4.460	West Virginia	40.0
North Carolina	198	Missouri	4.236	Virginia	39.6
Kentucky-Tennessee	196	Ohio	4.059	California	33.4
Virginia	189	New England	3.960	Florida	32.5
Wisconsin	183	Iowa	3.492	Southwest	31.3
Rocky Mountain	167	North Central	2.552	Pennsylvania	28.4
Iowa	132	Arizona	2.100	Canadian	‖
West Virginia	96	New Jersey	0.413	Illinois	‖
Nebraska	95	Cuban	§	Missouri	‖
Arizona	71	Montana	§	New England	‖
Montana	51	Pacific Northwest	§	New Jersey	‖
Cuban	46	West Virginia	§	New York	‖

* Numbers of members.
† Weighted gain in membership.
‡ Percentage of members present at annual meeting.
§ Minus score.
‖ Data not available or section not competing.

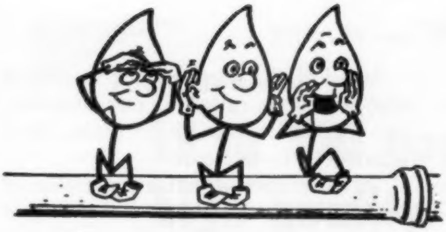
AWWA Membership Growth

Membership Statement—Year of 1955

	Active	Corporate	Munic. Serv. Subscriber	Associate	Honorary	Junior	Affiliate	Total
Total members, Dec. 31, 1954	8,349	881	212	369	42	42	45	9,940
Change of grade, 1955	6				3	−8	−1	
	8,355	881	212	369	45	34	44	9,940
Gains:								
New, 1955	1,091	72	35	24		19	3	1,244
Reinstated, 1955	72	9	3	5			1	90
	9,518	962	250	398	45	53	48	11,274
Losses:								
Resignations and deaths, 1955	−217	−15	−3	−30	−3	−2		−270
Dropped for nonpayment, 1955	−512	−31	−10	−17		−4	−4	−578
TOTAL MEMBERS, Dec. 31, 1955	8,789	916	237	351	42	47	44	10,426
Net gain in 1955	440	35	25	−18		5	−1	486

Comparative Statement—Gains and Losses—25-Year Period

Year	New	Reinstated	Resignations and Deaths	Suspended for Nonpayment of Dues	Gain or Loss	Total Members at End of Year
1931	203	22	123	216	114−	2,717
1932	117	22	169	297	327−	2,390
1933	168	56	159	234	169−	2,221
1934	271	66	86	122	129+	2,350
1935	565	42	85	190	332+	2,682
1936	311	53	104	218	42+	2,724
1937	515	86	122	139	340+	3,064
1938	520	59	144	140	295+	3,359
1939	578	64	122	179	351+	3,710
1940	514	58	113	212	247+	3,957
1941	480	92	116	236	220+	4,177
1942	570	59	132	233	264+	4,441
1943	769	88	130	198	529+	4,970
1944	734	92	140	171	515+	5,485
1945	543	56	111	235	253+	5,738
1946	816	79	168	324	403+	6,141
1947	933	74	143	349	515+	6,656
1948	847	81	207	347	374+	7,030
1949	1,083	75	196	323	639+	7,669
1950	852	58	128	421	361+	8,070
1951	1,090	63	199	441	513+	8,583
1952	1,005	66	232	505	334+	8,917
1953	1,077	99	263	370	543+	9,460
1954	1,160	69	256	493	480+	9,940
1955	1,244	90	270	578	486+	10,426



Percolation and Runoff

On the go—and on the grow—despite its Diamond Jubileeery, AWWA is scheduled to celebrate its 75th birthday, March 29th, in an especially significant, if not quite usual, manner—moving, that is, to larger quarters. The new address:

2 Park Avenue
New York 16, N.Y.

That's at the bottom of Park Avenue —geographically, at any rate—the building covering the block between 32nd and 33rd Streets at the point where Fourth Avenue gets more expansive and more expensive in changing its name. Equidistant and walkingdistant from Grand Central and Pennsylvania stations, the location is convenient not only for the staff, but for visiting watermen. And if the view from No. 2's seventeenth floor isn't quite as breathtaking as that from AWWA's present penthouse, neither is the approach to it, the elevators stopping at the office door instead of one or two steep flights below.

Taking over a portion of what, for more than 25 years was Boy Scout headquarters, the Association has already taken over its prelessee's well known motto. Thus, in increasing its office space approximately 50 per cent, it expects not only to accommodate the growth of the past 5 years, but to "be prepared" for future expansion. And to be prepared for receiving its members and guests a little more graciously, it is restoring the reception room that was crowded out of present quarters and providing a library-conference room for those who wish to consult AWWA publications and records, as well as for small meetings.

Come down and see us some time! But be prepared—get the address into your records right NOW!

Fluoridation works, but irks! That seems to be the only point of general agreement on a subject that has not only defied neutrality but invited extremes. "Fluoridation works, but . . ." has been the regular technique of the antis, and the pros have been the butt of every "but." Meanwhile, AWWA has managed to maintain its policy of official neutrality for almost 7 years now, still convinced that the experts in the fields of medicine, dentistry, and public health should decide whether, while water works men decide only how.

Most recently, the extremest of extremists in the anti camp have taken to rejecting even the one basic point. "Fluoridation doesn't work," they say; "proof that it does is merely a figment of the imaginations of those who are so biased in its favor they find what they want to find." On that basis, last year must have been a record one for figments, with Grand Rapids,

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Mich., Newburgh, N.Y., and Brantford, Ont., all producing the crop of a full decade of fluoridation on a controlled experiment basis. Actually, not only the figments, but the figment fanciers seem to have increased considerably, the January count showing more than 22,700,000 of them in 1,138 communities. With Chicago adding 4,000,000 to the total on March 1, Cleveland poised on the brink—awaiting equipment—and even New York seriously considering the idea, there is the promise, or threat, that an era of greatly improved dental health, or of greatly increased heart disease, nephritis, cancer, immorality, communism, insanity, and worse, is now at hand.

With as much scientific evidence in favor of fluoridation and with as many otherwise respected medical, dental, and health organizations endorsing the practice, it is sometimes a little difficult to understand the basis upon which so many people join the opposition. A reaction against scientific reason is one explanation; a normal emotional response to a play upon fear is another. Perhaps, though, it is merely the fact that most people can't understand why they should spend money to save "baby teeth" which are going to drop out anyway. Or perhaps, having learned by experience not to believe the dentist's "this isn't going to hurt," their opposition now is merely a conditioned response. At any rate, the controversy continues wherever the fluoridation issue is raised—in the home, in the newspapers, in the courts, or in the ballot. And though the antis always seem to have the last and loudest word and the longest and strongest applause, the weight of scientific evidence seems gradually to be tipping the scales in favor of fluoridation.

Some of the more recent fluoriding that has been called to our attention has followed a variety of paths, from courtroom to billboard:

In November, it was a courtroom of the Supreme Court of Ontario that was the scene of the first adjudication of the issue of fluoridation outside the United States. The verdict, citing cases from both the British and US bar, was in favor of fluoridation.

In December, the Ontario Department of Health, based upon its Brantford experiment, officially declared fluoridation an "effective and safe" public health practice.

In December, too, the president of the American Dental Association took the offensive against antifluoridationists with a strong statement, pointing out that those who do not fluoridate "are simply failing in their responsibility to the public."

In January, the state supreme court decided a Bend, Ore., taxpayer's case in favor of fluoridation, noting that it was a public health measure within the city's police powers to enact.

In January, the Long Island Federation of Women's Clubs came out against fluoridation as "compulsory mass medication."

In January, the supreme court in Fredericton, N.B., declared fluoridation illegal on the basis that it was outside the provisions of the Provincial Health Act.

In January, the New York City Council, having received its third recommendation and report from the city health department favoring fluoridation, held a public hearing at which AWWA's testimony received special attention as the only neutral opinion.

And in January, riding the you-know-what of public interest, Crest

(Continued on page 38 P&R)

(*Continued from page 36 P&R*)

toothpaste "with fluoristan," Procter & Gamble's "exclusive fluoride compound, *far superior to fluoride alone*" (italics P&G's), started an allout campaign to promote this "turning point in man's age-old struggle against this almost universal disease."

Finally, in February, in a letter to the Niagara Falls, N.Y., city council, a group of antifluoridationists indicated that it was compiling a tourist directory "for the benefit of the forty million Americans who voted against fluoridation" and also planned the erection of "suitable" signs at the outskirts of all communities that fluoridate their water.

Sometimes neutrality, too, *works, but irks!*

Marshall P. Crabill has been appointed to the newly created position of manager of operations of the Indianapolis Water Co. The job carries with it direct responsibility for all matters pertaining to the operation and maintenance of the purification, pumping, and distribution departments. Mr. Crabill was superintendent of purification for the last seven of his 23 years with the company. The post of acting superintendent has been assumed by Robert J. Becker, assistant superintendent since 1951.

It was also recently announced that Thomas W. Moses has been elected to the Indianapolis Water Co. board of directors and named assistant to the president, H. S. Morse. Mr. Moses practiced law at Charleston, W.Va., and Pittsburgh, Pa., before joining Investments Management Corp. in Dallas, Tex., in 1955. He has been assisting Mr. Morse on a part-time basis since September.

Water resources policy has been under study by a presidential advisory committee created in May 1954. In January 1956 a report proposing a long-range program for the conservation and use of the nation's water resources was issued by the committee, consisting of the secretaries of interior, defense, and agriculture, with Secretary of Interior Douglas McKay as chairman. A number of other federal agencies and individuals participated. It was proposed that:

1. Increased money and manpower be directed to collecting basic data on rainfall, stream flow, and hydrology
2. Planning of water resources projects for various purposes be undertaken cooperatively by the federal, state, and local agencies concerned
3. A four-point organization plan to carry out such projects be set up, providing for (a) regional committees composed of federal and state officials; (b) a federal interagency committee to advise the President and to be headed by a coordinator of water resources in the Executive Office of the President; and (c) a board of review whose members would be totally separated from federal agencies and without involvement in projects coming before them—the board to be appointed by the President and to report to him through the coordinator.

The advisory committee also recommended that all aspects of potential water use be considered in the early planning stages to make certain that long-range uses were not overlooked; that the principles which recognize water rights as property rights be accepted; that all federal agencies adopt uniform procedures for evaluating project costs and benefits and for distributing costs among beneficiaries

(*Continued on page 40 P&R*)

(*Continued from page 38 P&R*)

in proportion to benefits; that the federal government help state and local governments to initiate and finance their own projects; and that each major project be separately authorized by Congress.

George J. Natt, senior engineer with the New York State Water Power & Control Commission, has been named director of the Westchester County (N.Y.) Water Agency. He succeeds Simon P. Carman, who has resigned to resume his private consulting engineer practice at Binghamton, N.Y.

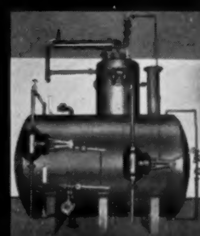
M. K. Tenny has been named general manager of the Des Moines, Iowa, Board of Water Works Trustees. He was formerly assistant to General Manager Dale L. Maffitt, recently deceased.

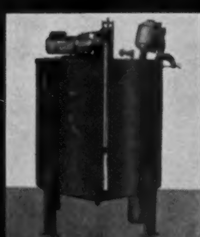
McIlroy is here and, unlike Kilroy, his sort of sanitary engineering predecessor, McIlroy is here to stay, it seems. At any rate, the Baltimore Water Dept. recently invested $36,000 in one of those hydraulic network analyzers which he described in the pages of the April 1950 JOURNAL, and the Philadelphia Water Dept. is now in process of installing a $42,000 version. Meanwhile, countless other water utilities have gone to McIlroy to analyze their systems on equipment set up at the Midwest Research Institute in Kansas City, Mo., the State College of Washington at Pullman, and Cornell University in Ithaca, N.Y. Although it isn't likely he'll ever attain the renown of his "Mc"-less forerunner, his, too, is the kind of pushbutton business that's just naturally popular.

(*Continued on page 44 P&R*)

what's the cost in the long run?

There's no dodging the question today. High costs and low budgets demand straight answers. The installation of water conditioning equipment is an important step that merits the careful consideration of every factor involved. Modern General Filter water conditioning installations are designed with a practical eye on original equipment and installation costs. Equally important, however, is the extent of continuing service available from the company with which you are dealing. General Filter's staff of highly trained engineers and chemists are at your call on a moment's notice. General Filter's 40 branches are located across the country to give you prompt dependable service. Make your own comparisons and you will join the hundreds of General Filter water treatment plants that are enjoying lower first cost — lower operating costs — lower maintenance costs.





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(Continued from page 40 P&R)

Thomas B. Nolan, a career Civil Service employee since 1924, has been appointed director of the US Geological Survey. Assistant director since 1944, he will succeed William E. Wrather, who is retiring after 12 years. Also retiring, after more than 45 years of government service, is Royal W. Davenport, chief of the Technical Coordination Branch, Water Resources Div., USGS.

Arthur C. Ford, commissioner, New York City Dept. of Water Supply, Gas & Electricity, has been elected first vice-president of the Society of Municipal Engineers of the City of New York.

Thomas A. Cole, bacteriologist, Poughkeepsie, N.Y., has moved his laboratory to 9 Edgar St. in that city.

T. W. Fauntleroy has been named general sales manager by Pittsburgh–Des Moines Steel Co. He succeeds John E. O'Leary, who has retired after 45 years with the company.

The sound of his name has long been recognized as the sweetest sound a man can hear, so it isn't at all surprising to learn that meter readers at Dothan, Ala., are working on the theory that the dogs along their routes will react just as friendlily. After all, "Bowser" or "Pooch" or "Mutt" must be just as offensive to our canine friends as "Mac" or "Bud" or "Chum" is to us. By noting the names in their meter books, Dothan readers are expecting to hail fidoes well met. And if the bite is still put on them, they will at least be able to call the mutts proper names.

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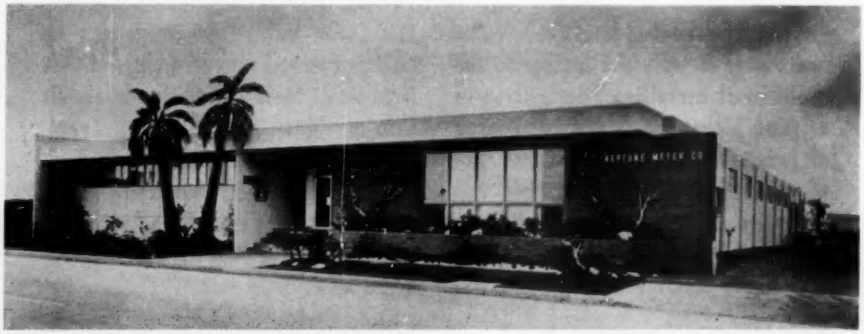
(*Continued from page 44 P&R*)

Whisky and water always have made a good combination, but perhaps never better than in Perth, N.B., this past winter. There, the cold weather, particularly during the Christmas season, froze up the brook which fed the town reservoir, leaving the only source of water supply a private well on the premises of the local liquor store. With a corner on both hard and soft drinks, the store was far and away the most popular place in town. It was not revealed, of course, whether the popularity might be due in part to a judicious addition of the one to the other to avoid the catastrophe of losing the last source of chaser.

Chester M. Brown is the new president of General Chemical Div., Allied Chemical & Dye Corp., New York. Formerly executive vice-president, he succeeds Mark M. Biddison, who remains with the company in an advisory capacity.

Evaporation losses from Texas reservoirs amount to about 7,000,000 acre-ft per year, almost equaling the 8,000,000-acre-ft annual water use in that state. In presenting these facts before a conference held at Southwest Research Institute, San Antonio, last December, water conservation expert Louis Koenig, vice-president of the institute, advocated further research on chemical coatings for reservoir water surfaces as a means of coping with the problem. Dr. Koenig stated that a 0.0001-mil film, sufficient to check evaporation and noninjurious to aquatic life or water quality, can be applied at a cost of less than $0.80 per acre-foot. The general manager of the Colorado River Municipal Water Dist., E. V. Spence, of Big Spring, Tex., was appointed chairman of a committee to seek sponsors for a research project on evaporation control.

R. L. Mitchell, formerly instrument engineer with Chemical Construction Corp., New York, has accepted the post of assistant to the secretary of the Chlorine Institute, Inc., New York. He succeeds C. E. Hepenstal, who has taken a position in the engineering de-



Neptune Meter Co. has opened its new Pacific Coast headquarters at 5540 E. Harbor St., Los Angeles. The building provides testing and repair facilities, as well as warehouse space.

(*Continued on page 48 P&R*)

(*Continued from page 46 P&R*)

partment of The Dow Chemical Co., Midland, Mich.

The open-mouth policy—during showers, that is—so strongly discouraged by our Iran correspondent in his tales from Teheran in February (P&R, p. 46) has suddenly become SOP * for our soldiers in France. Innocent initiator of the procedure was Master Sergeant George McElroy of Herrin, Ill., stationed with his unit in Bussac in southern France. Stepping into the shower in his apartment there one day last December, McElroy suddenly found himself swigging when he should have been swabbing. Meanwhile, his wife was pickling rather than plucking a chicken under the kitchen tap, as the plumbing throughout their quarters was pouring out white wine instead of water.

Official explanation of the incident in *Stars and Stripes* was: "In this region, the residents buy water when the wells are low. The same tank trucks sometimes are used to transport the wine of the region. The driver of the truck didn't know what kind of a load he was carrying." Which may be logical, but not reasonable in France, where water is for the birds and milk for Mendes-France. Besides, if water is short, is it even logical to haul it when a load that really can be a load can be called a conservation measure?

If it's lockjaw they get, it will be in the "open" position.

* Standard Operating Procedure, that is.

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Service Lines

Taste and odor control is the subject of an 80-page booklet issued by Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York 17, N.Y. The publication covers the history of control measures, causative agents such as algae (with photographs), determination of odor concentration, and methods of control, stressing activated carbon. Copies of "Taste and Odor Control in Water Purification" may be secured from the company.

Hose couplings said to insure freedom from leakage and to provide a full swiveling action that prevents kinking are described in the 20-page "Quick-Seal" catalog available from the Industrial Sales Dept. of Titeflex, Inc., 10 Hendee St., Springfield 4, Mass.

Venturi tubes and nozzles ("Type TG" inserts) are described in a 4-page brochure (Bul. 100) available from Simplex Valve & Meter Co., Lancaster, Pa. Data on advantages, construction and installation, size ranges, and specifications are given in simplified form.

Deflection indicators, applicable to pumping stations, drive shafts, and other equipment in which early detection of relative movement is desirable, are offered by Allis-Chalmers Mfg. Co., 1026 S. 70th St., Milwaukee, Wis. The magnetic-amplifier device requires a 60-cycle, 110-v power source and a suitable location for mounting two compact inductor coil pickup units. An 8-page descriptive bulletin (No. 05B8385) can be obtained from the company.

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Service Lines

(Continued from page 50 P&R)

Red-water prevention in consumer piping by means of sodium silicate treatment of the incoming supply is described in Catalog Sheet CS-101, issued by The Permutit Co., New York 36, N.Y. Copies can be secured from the company.

Remote supervisory control apparatus by the all-relay "Visicode" system is illustrated and described in detail in Bul. 32-450 (18 pages), obtainable from Westinghouse Electric Corp., Switchgear Div., East Pittsburgh, Pa.

Glass fiber products, their properties and applications, are covered in an 8-page catalog (WPD-11) available on request from L.O.F. Glass Fibers Co., 1810 Madison Ave., Toledo 1, Ohio.

B-I-F Industries has issued a 4-page bulletin (No. 840-L23B) on the "Builders Model EVS Chlorinizer," including information on operation, methods of control, and safety features. Also available is an 8-page bulletin (No. 230-H4A) on "Chronoflo" telemeters, containing sections on application and operation, as well as photographs of the equipment and installation diagrams. Requests for copies should be addressed to Builders-Providence, Inc., 345 Harris Ave., Providence, R.I., and should mention the number of the bulletin desired.

Pumps for medium and high services are described in an 8-page catalog (No. A-155) available from Economy Pump Div., C. H. Wheeler Mfg. Co., 19th St. & Lehigh Ave., Philadelphia 32, Pa. Construction details and cross sections of Wheeler-Economy "Type M" pumps, bottom suction and side suction, are shown.

Steel shelving, lockers, and other storage and maintenance items are illustrated in a 16-page catalog available from Precision Equipment Co., 3700 N. Milwaukee Ave., Chicago 41, Ill.

Professional Services

Professional Services

Professional Services

Professional Services

Professional Services

Condensation

Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

FLUORIDATION

The Value of Fluoridation of Domestic Water Supplies in Prevention of Dental Caries and Dental Sepsis. J. H. C. CLARKE. J. Br. Waterwks. Assn., **36**:497 ('54). A detailed survey was carried out on teeth of schoolchildren in Kesteven district of Lincolnshire, where water supplies from boreholes contain fluorides in concentrations varying from nil to 4 ppm as F. Investigations showed that F in a concentration of 0.7 ppm or less did not reduce the amount of dental caries, but that a concentration of 2.5 ppm greatly reduced dental caries and did not produce any undesirable mottling of enamel. In area where water contained up to 4 ppm F, there was evidence of white and brown mottling of teeth. Reference is made to prophylactic effect of fluoridation on dental sepsis and diseases attributed therto, and to occurrence of fluorosis. Fluoridation of water supplies is recommended, and it is pointed out that there is no risk of fluorosis when recommended dose of 1.2–1.5 ppm F is used.—*WPA*

Medical Aspects of Excessive Fluoride in a Water Supply. N. C. LEONE ET AL. (Natl. Inst. of Dental Research, Bethesda, Md.). Pub. Health Repts., **69**:925 ('54). A 10-year study of 116 persons in Bartlett and 121 in Cameron, Texas, was conducted to det. if prolonged exposure to F in the water supply of Bartlett had produced detectable physiol. effects. Bartlett's water contained about 8 ppm F until 1952, when an exptl. defluoridation unit was installed, reducing the F content to approx. 1.2 ppm. Cameron was the control area with 0.4 ppm in its water supply. The participants, aged 15–68 in 1943, were chosen at random from persons who had resided in the respective communities for at least 15 years. The avg length of F exposure in 1953 was 36.7 years. In 1943, the investigators took medical histories and gave each participant a medical, x-ray, and dental examn. In 1953, this procedure was repeated for all the original participants, except the 18 deceased and 10 of the 47 persons who had moved away from the 2 towns. No significant differences between the findings in the 2 towns were observed, except for a slightly higher rate of cardiovascular abnormalities in Cameron and a marked predominance of dental fluorosis in Bartlett. 15 references.—*CA*

The Evanston Dental Caries Study. XI. The Caries Experience Rates of 12-, 13-, and 14-Year-Old Children After Exposure to Fluoridated Water for 59–70 Months. I. D. HILL, J. R. BLAYNEY & W. WOLF. J. Dental Research, **34**:1:77 (Feb. '55). Sodium fluoride sufficient to produce 1 ppm fluoride ion first added to water supply of Evanston, Ill. on Feb. 11, 1947. Present study completed during 1952 concerns only 3 children who were 7, 8 and 9 yr old at beginning of fluoridation. Among 1,554 children of this group examd., decayed, missing, and filled permanent teeth were reduced approx. 18.5%, greatest reduction (21.8%) occurring in 12-yr-old group.—*F. J. Maier*

Cariostatic Effect and Metabolism of Ammonium Fluosilicate. I. ZIPKIN & F. J. MCCLURE. Pub. Health Rpts., **69**:730 ('54). Comparison made of ability of NaF and $(NH_4)_2SiF_6$ solns. contg. 5 ppm F to reduce caries and deposit F in bones and teeth of white rats. No differences were observed in amt. of F and ash deposited in molars, incisors, mandibles, and femurs. No difference in rate of growth among all groups of rats. No difference in production of incisor striations. $(NH_4)_2SiF_6$ was as effective as NaF in inhibiting caries in white rats. Data sug-

(*Continued on page 64 P&R*)

Installation of "American" Ferrofilters and "American" Double Suction Split Case Pumps at Columbus, Indiana Water Plant • Consulting Engineers, Henry B. Steeg & Associates, Inc., Indianapolis, Indiana.

Independent tests and observations of "American" Ferrofilter operation at the Columbus, Indiana water plant show reduction to .15 ppm on 1.8 MGD loading/filter. (Units are rated 1.5 MGD.) Even on excess loading of 2.5 MGD/filter with all six wells on, iron reduction was still getting down to .2 ppm.

The "American" Ferrofilter is a contact filter that offers many advantages as a complete process or as a preliminary process—for the removal of iron, manganese, carbon dioxide, and other dissolved gases and odors, in one simple operation. It combines fundamental processes and design in an effective and economical treatment plant. Utilizes fine media in open aeration. Can be backwashed to remove any excess accumulation, leaving the filter in condition for another cycle. In most cases, it eliminates the need for a sedimentation tank or sand filter.

Write for Bulletin No. 252B or for specific information relating to your application.

Utilize our experience in engineering design and manufacture of field-proved equipment and pumps for water and waste treatment.

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gest that $(NH_4)_2SiF_6$ may be as effective as NaF as F carrier for fluoridation of municipal water supplies.—*CA*

SOFTENING AND IRON REMOVAL

Anionic Softening of Water with Strong Base Anion Exchange Resins. R. Kunin & F. McGarvey. Ind. Eng. Chem., **47**:1230 (Jun. '55). Fluorides, sulfides, carbonates, bicarbonates, and silica have caused difficulties in use of many water supplies. Fluoride concn. in drinking water greater than 2 ppm (as F) results in mottling of teeth, as well as lesions of endocrine glands, thyroid, liver, and other organs. Fluoride concn. in water may create hardship in food and packing industry. Sulfide concns. as low as 0.5 ppm give objectionable taste and odor. Carbonates and bicarbonates are undesirable when water is to be used for preparation of carbonated beverages or for boiler feed, while silica in water is troublesome in high-pressure boilers and turbines. As result of previous studies, it became apparent that certain quaternary ion exchange resins might be capable of adsorbing fluoride, sulfide, and bicarbonate ions in exchange for chloride ions. 4 quaternary anion exchange resins were selected, for this study, 2 of them being std. and 2 being porous analogs of stds. Resins were studied in 1-in. columns contg. 250 ml resin. Exhaustion flow rate was limited to value of 2 gpm/cu ft and regeneration to 1 gpm/cu ft using 10% salt solns. In concurrent operation, exhaustion and regeneration were downflow, whereas, in countercurrent operation, exhaustion was upflow and regeneration was downflow. Fluoride anals. were volumetric, using thorium nitrate. Sulfides were detd. colorimetrically with antimony potassium tartrate. Bicarbonates were analyzed volumetrically with 0.1*N* hydrochloric acid. Ion exchange process was effective and easily regenerated with some advantages to operation in countercurrent direction. Operational equipment

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need not be acid resistant. Technique is simple, and economics of regeneration are favorable.—*PHEA*

Applicability of Water Softeners in Industrial Boiler Plants. I. F. SHAPKIN. Energet. Byull. (USSR), No. 9, p. 16. Industrial boiler plants in USSR use Na cationic and soda-regenerative water softener. These 2 types are not competitive but supplement each other. Cationic type is limited by alky. of feed water and, hence, by temporary (carbonate) hardness of softened water, which should not exceed 1.82 mg equiv/1, while regenerative type is not limited as regards temporary hardness but is not advantageous for permanent hardness exceeding about 3 mg equiv/1. On adding increasing amts. of condensate, admissible limits for hardness of treated water are correspondingly increased.—*CA*

Hot Lime-Zeolite Will Save $49,000 Yearly at Ford's Rouge Power Plant. L. F. O'REILLY, A. K. SUKUMAR & W. J. FADDEN JR. Power, **99**:1:96 ('55). Hot lime-soda plant is being replaced by hot lime-zeolite at material saving. Oil is removed in hot lime sludge. 7 units operating in parallel comprise hot-zeolite softeners. Water passes through anthracite-supported bed of resinous zeolite. Entire plant is described.—*CA*

The Rate of Ion Exchange. E. R. GILLILAND & R. F. BADDOUR. Ind. Eng. Chem., **45**:330 ('53). Results given of exptl. work on effect on rate of ion exchange of particle size, concentration of ions in solution and in resin phase, rate of flow, and height and diam. of bed. Tests were made with fixed bed of anion-exchange resin in hydrogen form. From theoretical considerations, equation was derived for expressing rate of exchange assuming that it is limited by rate of mass transfer. This equation was used to correlate data obtained from exptl. runs over range of conditions tested and could be used to estimate results for other conditions from knowledge of fundamental properties of ionic soln. and of exchange material.

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Results of expts. indicated that over range of variables tested, rate constant for ion exchange in packed beds is not function of height or diam. of bed as long as diam. is at least 20 times diam. of particles. Rate constant is affected by concn. of ions in liquid phase and effect can be calcd. fairly accurately. Resistance in both liquid and solid phases is important in detg. total resistance to ion exchange. Elutriation curves for exchange of hydrogen ions in liquid phase for sodium ions on resin can be predicted from data for reverse process.—*WPA*

Variation of Alkalinity in Cation-Exchange Treated Waters. C. CALMON & G. P. SIMON. Ind. Eng. Chem., **46**:2404 ('54). Variation of alky. in effluent from various cation-exchange materials during softening cycle was studied. Exchangers investigated were: natural siliceous, synthetic siliceous, sulfonated coal, sulfonated phenolic, ω-sulfonated phenolic, and sulfonated polystyrene. Sulfonated polystyrene resin was only one which showed practically no variation regardless of CO_2 content of influent water. Effect in case of other exchangers is ascribed to presence of weak acid exchange groups which lend themselves to hydrolysis in exchanger with resultant release of NaOH which increases alky. Eventually, H on resin is replaced by bivalent ions and thus also has effect on alky. during latter part of softening cycle.—*CA*

Theory and Practice of Demineralization. W. WESLY. Chem. Ing. Tech. (Ger.), **25**: 623 ('53). Summary of paper presented at annual meeting of Vereinigung der Grosskesselbesitzer, July 1953. On basis of experimental work and practical experience, author draws following conclusions. Carbonate in water should be removed with lime or by conversion in cation-exchange material into carbon dioxide which is then removed by aeration. Cation-exchange material must decompose salts as completely as possible; "hide-out" (amount of uncombined cations) must be small. Monovalent ions tend more than divalent ions to hide out. The specific

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load (volume of water per unit volume of material) determines amount of exchange material required; exceptionally small or large specific loads decrease efficiency of exchange. The capacity increases with amount of regenerant used but so also does cost; in general moderate excess of regenerant is used. Before regeneration exchange material must be loosened by back-washing; regenerant must be washed out; water used for these purposes must be taken into account in reckoning costs. 9 different arrangements can be used according to requirements for treated water; they cover combinations of cation- and anion-exchange materials with or without gas-removing and buffer filters. Organic matter remains in treated water and oxygen must be removed by degasification or treatment with hydrazine. Automatic apparatus, such as conductivity and pH meters, must be used to indicate exhaustion of material. Complete removal of salts is best carried out at normal temperature. The process reduces silica to undetectable amount.—*WPA*

CHEMICAL ANALYSIS

Microdetermination of Calcium. A Colorimetric and a Nephelometric Method. E. L. Richards. Dissertation Abstr., **13**:16 ('53). 2 methods for microdetn. of Ca are described. Colorimetric method consists in pptg. Ca as molybdate and treating it with K thiocyanate and stannous chloride in sulfuric acid to form red-orange Mo thiocyanate complex. Absorption is measured at 3170Å or 4580Å. Phosphate interferes but Mg does not. In nephelometric procedure, Ca is pptd. as molybdate in 80% alcohol soln. Fe, Ba, and Sr interfere, but Mg and sulfate do not. Phosphate inhibits pptn. of molybdate.—*WPA*

Determination of Fluorine in Water. J. A. Stevens. S. African Ind. Chemist (U of SA), **8**:83 ('54). Author reports that in detg. fluorides in water contg. phosphates, Ba chloride solns. used to remove phosphates, sulfates, and carbonates according to method of Bond and Murray affected titra-

(*Continued on page 74 P&R*)

Which uses the most water?

Filling Station —or Church Building?

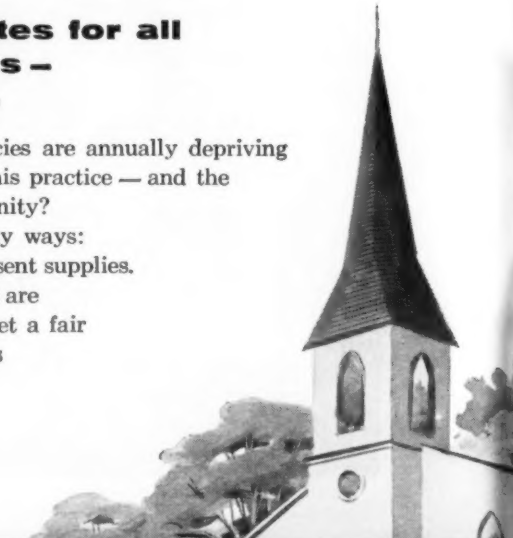
ANSWER: Before one Midwestern community installed water meters, gas stations were billed a flat rate of $12 per year; so were the churches. Last year, the average bill for all filling stations was $48, while in only one case did a church use more water than the minimum charge of $7.20.

Badger water meters provide fair rates for all users – help conserve vital resources – key to the future of your community.

The above is a typical example of how flat-rate water policies are annually depriving water departments of thousands of dollars of revenue. Is this practice — and the *water waste* that goes with it — a problem in your community?

Studies show Badger meters serve vital water needs many ways: (1) Each customer becomes a self-interested guardian of present supplies. (2) A fair allotment of available water is assured. (3) Users are charged for exact amounts used. (4) Water departments get a fair price for water and service. And, (5) greater efficiency helps keep water departments self-supporting.

Water is vital to industrial, business and residential development. Make certain you act NOW to safeguard your community's future — specify Badger water meters.



(*Continued from page 70 P&R*)

tion to greater extent than reported by them; fairly rapid ppn. of pink lake was caused and Ba phosphate was not completely pptd. Method adopted was to dist. Fl from sulfuric acid in presence of Ag sulfate and to det. F in distillate as described by Stevens except that check titration proved unnecessary. With low concns. of Fl very dilute Th nitrate solns. are required for back titration; it was found that when alizarin soln. is added to weak Th nitrate soln. pink lake may take several hr to develop, whereas if procedure is reversed and Th nitrate is added to alizarin lake develops immediately.—*WPA*

Determination of Iron in Waters. R. Buydens & R. Muylle. Bul. Centre Belge Etude Document. Eaux. (Belgium), No. 23, p. 52 ('54). In continuation of study of spectrophotometric methods of detg. Fe in natural waters, use of thioglycollic acid and of disodium 1:2-dihydroxybenzene-3:5-disulphonate have been investigated. In both cases, Beer-Lambert law was obeyed, but for natural waters, methods were less sensitive than those using thiocyanate, α α'dipyridyl or *o*-phenanthroline. Last 3 methods were compared in anal. of 4 natural waters. *o*-phenanthroline method gave lower results than other 2, and recovery of added Fe was incomplete. It was found that in thiocyanate method, Beer-Lambert law is obeyed if pH is less than 0.5, if there is no excess of H peroxide, and if 3 ml ammonia persulfate or nitric acid/100 ml water are present. Methods of detg. Fe complexed with org. compds. are discussed. Method is recommended in which sample is evaporated to dryness in Pt crucible and heated to redness for 2–3 min, and residue is taken up in nitric acid, dild., and analyzed as described. This method gives higher results than classic direct-oxidation method.—*WPA*

Determination of Iron in Water. II. R. Buydens & R. Muylle. Bul. Centre Belge Etude et Document Eaux (Liege), No. 23, p. 52 ('54). 5 methods were compared, in which thioglycolic acid, Na salt of 1,2-dihydroxy-3,5-benzenedisulfonic acid (**I**),

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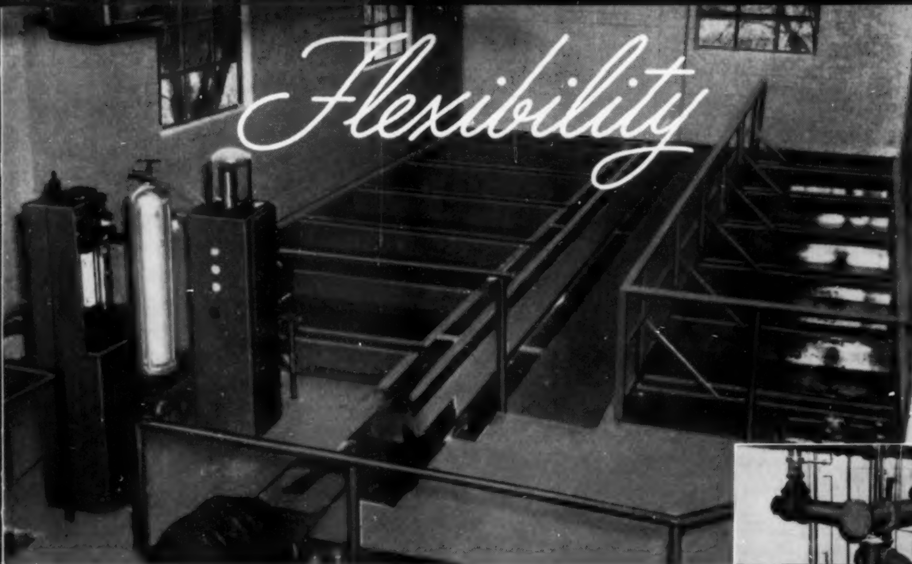
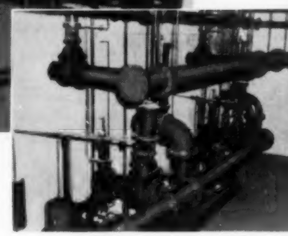
thiocyanate (**II**), o-phenanthroline, and 2,2′-bipyridine (**III**) were used. Methods in which **II** and **III** were used gave best reproducible results. In method in which **I** was used, pH was adjusted with NH_4OH without use of buffer. In method in which **II** was used, there was slight deviation from Beer-Lambert rule; however, by applying pH <5 without excess H_2O_2 and in presence of NH_4 persulfate or HNO_3, there was no deviation from above rule.—*CA*

Some Notes on the Determination of Dissolved Oxygen. Wtr. Poln. Research Lab., Dept. Sci. & Indus. Research (Br.); Wtr. Poln. Abstracts (Br.), **27**:2:48 ('54). Survey is made of methods used in determination of DO, including gasometric, electrical, and titration methods; experimental investigations on methods of determining concentration of DO in water are described. Using potentiometric method for determining end-point of titration in Winkler determination, it was shown that starch indicator can give negative errors of 20–40 μg of iodine in samples of 50–200 ml, which is equivalent to 0.02 ppm DO in 100-ml sample. With 5-ml sample, error becomes 0.4 ppm. By using apparatus for carrying out Winkler determination in absence of air, it was shown that, in normal method, using stoppered bottles, there is no great error due to contamination with atmospheric oxygen during addition of reagents. When samples which could not be analyzed at time of sampling were allowed to stand after formation of precipitate and before final acidification, titers increased slightly with period of standing; increase was apparently due to contamination with atmospheric oxygen. Method for automatic control of concentration of oxygen in water entering tanks used for tests with fish is being developed. Experiments are in progress to adapt Van Slyke volumetric apparatus. Present apparatus gives slightly lower results than Winkler method, but sulfite in concentrations of 140 ppm and nitrite in concentrations of 5 ppm do not interfere. Review of literature is included in paper.—*WPA*





FILTER PIPE GALLERY

of Cochrane SOLIDS-CONTACT REACTOR

simplifies operation at Vandalia, Illinois

The Kaskaskia River, Vandalia, Ill., is characterized by wide variation in composition (hardness from 50 to 360 ppm; alkalinity 35 to 280 ppm; turbidity from 10 to 3,000 ppm; temperature from 33° to 85° F.). This variation requires considerable flexibility in water softening and clarification treatment methods using lime, alum and carbon.

This Cochrane rectangular Solids-Contact Reactor 30′ long x 19′ wide was chosen by municipal engineers for recent plant expansion. It combines chemical mixing, precipitation, sludge concentration and solids separation within one unit. With a retention time of only 80 minutes, the new Reactor treats 700 gpm of water, reducing the hardness down to an average of .05 ppm and turbidity down to 2 to 5 ppm. It has more than doubled the length of filter runs compared to previous operations with conventional settling basins having as much as 5 hours retention time.

Cochrane's complete municipal water conditioning systems provide higher quality treated water faster, and at less cost than other conventional methods. Write for pamphlet entitled, "The New Water Clarification and Softening Plant at Vandalia, Ill.", and for Cochrane Publication 5001-A.

Cochrane also manufactures circular reactors

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**Demineralizers • Hot Process Softeners • Hot Zeolite Softeners • Dealkalizers • Reactors
Deaerators • Continuous Blowoff • Condensate Return Systems • Specialties**

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Fischer & Porter Co., Hatboro, Pa., has introduced a new series of variable-area flowmeters with simplified design features, as well as improvements in sturdiness of construction and visibility of the metering tube. The new "1700 Series Flowrator Meter" has the same overall dimensions as the earlier 700 series, permitting substitution of the later model without costly pipe changes. Descriptive literature is available from the company, at Hatboro 35, Pa.

The "London Britches" of January's Correspondence column (P&R, p. 50) had no more than gone to press when word of dyed dydees at Mendham, N.J., was received. A little less complicated chemically, Mendham's rosy rompers were no less of a problem to local authorities, the Borough Council being all but swamped with claims for ruined clothing—particularly baby wash—as a result of the red-water troubles stirred up in the cleaning of 15,000 ft of main. As a matter of fact, when the shouting about nitey-nites, creepers, snuggies, smalls, and other forms of pantie-wanties was the loudest, Supt. Robert Snedaker was all for putting back the incrustation that had cut his main capacity as much as 60 per cent before the cleaning. The more professional flushing, however, the less personal flushing, until his dyed dydee diet died down.

Next month, perhaps, some chartreuse shorts.

The "do-it-yourself" fad that was born of wartime shortages of help and

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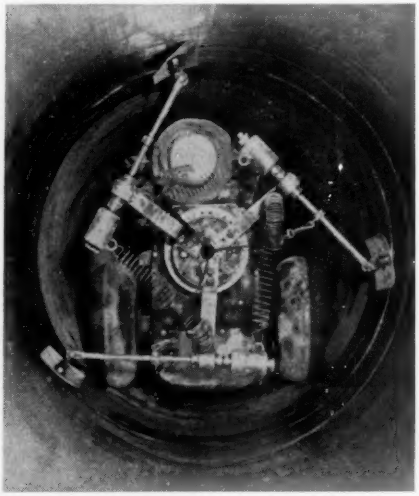
fostered by the skyrocketing prices of skilled tradesmen since then has apparently gone so far astray now as to invade even the water works field. Thus, at Ottawa, Ill., last December, a survey by a citizens' advisory committee disclosed that 90 of the homes enjoying the benefits of the public water supply had never even been entered on the books of the water department. Such sub rosa tapping might be less surprising—though probably more shocking—in the economically significant field of electric service, but with the price of water what it is we can see in it little more than an overenthusiasm for basement shopping—in this case, perhaps, dew it yourself!

Lining of San Francisco's 47½-mile San Joaquin Pipeline No. 1 was re-



cently completed by Pipe Linings, Inc., using machines of the type illustrated above. Averaging 58½ in. in diameter, the pipeline is believed to be the longest ever cement-mortar lined in place. The project was started in the summer of 1952.

Ralph Stone, consulting engineer, has moved his office to new and larger quarters at 147 San Vicente Blvd., Beverly Hills, Calif. The firm name has been changed to Ralph Stone & Co., Consulting Sanitary & Civil Engrs.

Thomas H. Chilton, technical director, E. I. du Pont de Nemours & Co., is the new president of Engineers Joint Council. Dr. Chilton, formerly EJC vice-president, succeeds Thorndike Saville, dean of the College of Engineering, New York University.

A tenoning tool for asbestos-cement pipe, adaptable for cutting any type of profile and machining ends to take various couplings and flange assemblies, is being marketed by Spring Load Mfg. Corp., 3610—1st Ave. S., Seattle 4, Wash. The "ACT–Model B" is said to feature completely automatic feed and quick release, and to be so light in weight that it can be operated by one man.

K. T. Snyder Co., of Houston, Tex., has been appointed national sales agent by the Gulf States Asphalt Co., South Houston. Mr. Snyder was formerly sales manager of Atlas Mineral Products Co., Houston.

Chain Belt Co., Milwaukee, Wis., announces the appointment of W. B. Marshall, formerly sales promotion manager, to the new position of manager—market development and sales training. G. H. Pfeifer, formerly advertising manager, becomes manager—sales promotion and advertising.

Samuel J. Bargh, vice-president of American Water Works Service Co., died at his home in Greenwich, Conn.,

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Dec. 25, 1955, at the age of 49. From 1946 to 1949 he was president of the Greenwich Water Co. and the Port Chester (N.Y.) Water Works, while serving as division manager for the parent firm, American Water Works Service Co. In 1949 he was named New England division manager, a post he retained until October 1955, when he was appointed vice-president, with offices in Philadelphia.

Joseph L. Hodgson, a sales representative for many years throughout the Southeast, died Dec. 17, 1955, at the age of 71. Born at Atlanta, Ga., in 1884, he moved to Athens, Ga., as a child, and there attended the University of Georgia. He was graduated in 1902 with a degree in engineering and worked in the Atlanta Water Works. He started his water works sales career with the Thomson Meter Co., remaining until the outbreak of World War I. Upon his return from military service, he became associated with the National Meter Co. Later he pioneered as a salesman for A. P. Smith Mfg. Co. in the Southeast and also took on the representation of National Water Main Cleaning Co. and Joseph G. Pollard Co. For the past few years, having retired from A. P. Smith and Pollard, he had served as an advisor to National Water Main Cleaning Co. in its sales effort throughout the Southeast.

The water works industry in the Southeast has lost a tried and true friend as well as a fine gentleman of the old school.

Joseph Laherran, superintendent of the Santa Clara, Calif., Water Dept., died Aug. 11, 1955, at the age of 56. Employed by the city for 36 years, he was familiarly known as "The Chief," having served as fire chief of the voluntary fire department until ill health forced him to relinquish the post in 1951. His friendly smile and warm personality will be greatly missed.

H. Lloyd Nelson, director of market research, promotion, and product scheduling, US Pipe & Foundry Co., Birmingham, Ala., died Dec. 27, 1955, after a short illness. He was 52. Born in Philadelphia, he held a degree in civil engineering from the University of Pennsylvania and was a registered professional engineer in that state. He joined US Pipe & Foundry Co. in 1924. During World War II he served with the Utilities Branch of the War Production Board and, during the Korean emergency, with the National Production Authority on a part-time basis.

An AWWA member since 1930, Mr. Nelson was a director in 1938–39, representing the Central States Section. He was also secretary-treasurer of the latter, as well as of the Four States Section, which gave him the Fuller Award in 1946. Other professional societies to which he belonged include ASCE, FSIWA, and NSPE.

Hymen Shifrin, partner in the firm of Horner & Shifrin, Cons. Engrs., St. Louis, died suddenly of a heart attack Nov. 22, 1955. He was 62 years old. A graduate of Washington University in St. Louis, with the degree of Bachelor of Science in Civil Engineering, he was a prominent civic leader and was active in many engineering organizations. Before the formation of the firm of Horner & Shifrin in 1933, Mr. Shifrin was assistant chief engineer for the Div. of Sewers & Paving at St. Louis. He was a World War I veteran and saw duty in Europe as a lieutenant in the Engineer Corps.

Section Meetings

Florida Section: The Florida Section again held its annual convention jointly with FSIWA Nov. 6–9, 1955, at Orlando. The convention officially began with a get-acquainted party and smorgasbord on Sunday evening, Nov. 6, following the trustees meeting. The technical sessions began the next day. (A list of subjects and authors appeared in the December 1955 JOURNAL, p. 1231.)

At the business session on Wednesday, the Section elected John Kelly, of Gainesville, chairman and Stanley Sweeney, of Pensacola, vice-chairman. J. D. Roth, of Miami Beach, was elected secretary-treasurer.

The annual banquet and dance was held Wednesday evening, at which time the section awards were made. The Alvin Percy Black Award was presented to Clifford E. Earls for getting the most members during the year, and Mr. Earls was also nominated for the Fuller Award. Another outstanding social event was a barbecue Monday night, with the Orlando Utilities Commission playing host to the 306 registrants.

The ladies again came in for some special entertainment when they were guests at a luncheon and fur show at the country club on Monday. On Tuesday they visited the Tupperware Plant and were given another luncheon.

This was one of the best attended and most interesting conventions ever held by the Florida Section and will no doubt result in better attendance at future meetings.

HARVEY T. SKAGGS
Secretary-Treasurer

North Carolina Section: The North Carolina Section held its 35th annual convention at the Robert E. Lee Hotel in Winston-Salem Nov. 14–16, in conjunction with the North Carolina Sewage & Industrial Wastes Assn. A list of the papers presented at the technical sessions will be found on p. 1235 of the December 1955 JOURNAL.

One of the highlights of the meeting was the buffet supper, entertainment, and informal dance given through the courtesy of the city of Winston-Salem. Another highlight was the annual banquet, at which the Fuller Award was presented to Edward R. Tull, superintendent of utilities, Rockingham. The Maffitt Membership Cup, awarded annually by the city of Wilmington to that member who is instrumental in procuring the greatest number of new members for the Section was won for the second time by Mrs. Ethel Young of Raleigh. Joe King of Winston-Salem entertained the members and guests with his ventriloquism. Following the banquet, the Association Dance was held on the Balinese Roof of the Robert E. Lee.

Officers elected at the business meeting were: R. S. Phillips—chairman; C. W. Mengel—vice-chairman; W. E. Long Jr. —secretary-treasurer; and F. R. Blaisdell—trustee.

A most enjoyable aspect of the convention was the fellowship and entertainment provided by the members of WSW MA. For the ladies attending the meeting there was bridge, a luncheon, a fashion show, and an inspection trip to Old Salem and the Vogler House.

W. E. LONG JR.
Secretary-Treasurer

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Section Meetings

(*Continued from page 84 P&R*)

Virginia Section: The 22nd annual meeting of the Virginia Section was held at Hotel Roanoke, Roanoke, Nov. 3–5, 1955. Chairman G. H. Ruston, manager of the Roanoke Water Dept., presided. The attendance of 237 equaled the all-time high but was lower than expected, probably because the meeting had to be ended on Saturday owing to reservation difficulties. More than average interest in the technical sessions was generated by a well prepared program and by the excellent meeting facilities of the hotel. (A list of papers and their authors appeared in the December 1955 JOURNAL, p. 1237.)

The more than 50 ladies present were well entertained by a luncheon on Thursday, Nov. 3, at Dixie Caverns, some 15 miles from Roanoke. On Friday afternoon there was a card party at the hotel. All of the ladies at the banquet Friday night received corsages, a delightful Section custom dating back many years.

As has been the case for several years, WSWMA entertained with its "Club Room" on Thursday evening before dinner and on Friday before and after the banquet. This feature of the meeting has always been excellently managed and consequently a great success.

At the annual banquet, music and other entertainment were provided. In keeping with tradition, there were no speeches, but the various awards were presented. William B. Harman, manager, Newport News Waterworks Commission, was selected for the Fuller Award. Life Membership was conferred on Marsden C. Smith, chief water and research engineer, Dept. of Public Utilities, Richmond. In recognition of the occasion, Mr. Smith was also presented with a loving cup by fellow members of an extracurricular club formed at the national meetings. Bryant L. Strother, of du Pont Co., Richmond, received the Old Dominion Award, given by the Section to members who have been affiliated with AWWA for 20 years.

At the business meeting Howard F. Knoell, of Orange, was elected chairman; W. W. Anders, plant manager, Dept. of Public Utilities, Richmond, was elected vice-chairman; and S. M. Hodges, of Norfolk, was elected a trustee. Other officers of the Section are E. C. Coalson, of Bristol, a trustee; and J. P. Kavanagh, of Roanoke, secretary-treasurer.

J. P. KAVANAGH
Secretary-Treasurer

West Virginia Section: The seventeenth meeting of the West Virginia Section was held at the Waldo Hotel, Clarksburg, Oct. 20–21, 1955. Official registration was 152, of whom 4 were ladies. A list of the papers presented at the technical sessions may be found in the December 1955 JOURNAL (p. 1238).

Section Chairman Henry Gay was operating in his own backyard and, as presiding officer, he exerted every effort to have the meeting run on a smooth schedule. At the end of the meeting the

(*Continued on page 88 P&R*)

AWWA's 75th Birthday

Postage Meter Slug

For Diamond Jubilee year, all of AWWA's mail will carry the postmark recognition of that fact reproduced below. If you use a Pitney-Bowes meter and would like to add your celebration to AWWA's, a slug can be provided for any model except the DM. Specify model number. Price is $15.00.

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AWWA 1881–1956
75 years of PROGRESS IN PUBLIC WATER SUPPLY

Section Meetings

(*Continued from page 86 P&R*)

gavel was turned over to Charles Whitlock, local manager, West Virginia Water Service Co., Madison, who will serve as chairman during the coming year. Cecil Coffield, water commissioner at Parkersburg, will serve as vice-chairman. John Douglass, construction engineer, West Virginia Water Service Co., Charleston, was elected to a 3-year term as trustee.

The annual banquet was held on the evening of Oct. 20, with Ellis S. Tisdale, director, Interstate Commission on the Potomac River Basin, Washington, D.C., giving an address on the subject, "Raising Our Sights Toward Greater Conservation of Our Water Resources." "Tis" fathered the first water works organization in West Virginia, in 1925. He departed from the West Virginia hills in 1938 after 22 years with the State Dept. of Health and was welcomed back by host of friends. The other highlight of the banquet meeting was the Fuller Award announcement, honoring Prof. Henry Speiden, head, Dept. of Civil Engineering, West Virginia University, Morgantown. W. R. Logston, Hope Natural Gas Co., Clarksburg, and Chairman Gay emceed the introductions and other announcements following the banquet.

The Section will have a new secretary-treasurer during the coming year—Hugh Hetzer, engineer, West Virginia Water Service Co. Harry Gidley, who has served as secretary-treasurer since 1949, was honored with a luncheon and a present, consisting of a fine briefcase, on Thursday, Oct. 20.

The meeting closed Friday afternoon with a trip to view the construction of an earth fill impoundment dam which is a major item of the Clarksburg improvement program.

H. K. Gidley
Secretary-Treasurer

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NEW MEMBERS

Applications received Jan. 1–31, 1956

Adams, John M., Prin. San. Engr., Div. of San. Eng., State Dept. of Public Health, 602 Cordell Hull Bldg., Nashville, Tenn. (Jan. '56) *MRP*

Allen, Lawrence D., Supt., Water & Light Dept., Elberton, Ga. (Jan. '56) *MPD*

Atkins, C. H., Regional Engr., US Public Health Service, Health, Education & Welfare Dept., Washington, D.C. (Jan. '56) *RP*

Bauman, Ben, Asst. San. Engr., State Board of Health, 1330 W. Michigan St., Indianapolis, Ind. (Jan. '56)

Bedford, City of, Ivan H. Brinegar, Mayor, City Hall, Bedford, Ind. (Corp. M. Jan. '56)

Belfry, E. H., Sales, Anaconda American Brass Ltd., 8th St., New Toronto, Ont. (Jan. '56)

Benoit, Dee A., Supt., Water Dept., 119 E. 2nd St., Bicknell, Ind. (Jan. '56) *M*

Benson, H. Earl, Instrumentation Engr., Minneapolis Honeywell Regulator Co., 1900 Superior Ave., Cleveland 14, Ohio (Jan. 56) *P*

Berk, Ralph G., Hydr. Engr., Consoer, Townsend & Assoc., 360 E. Grand Ave., Chicago 11, Ill. (Jan. '56) *R*

Bishop, Henry, Mgr., Horsham Township & Warminster Township Water Authorities, 235 Upland Ave., Horsham, Pa. (Jan. '56) *MD*

Bolen, John T., Utilities Engr., Hercules Powder Co., Radford Arsenal, Radford, Va. (Jan. '56) *MPD*

Bradley, John C., Mgr., Charlotte Branch, General Chem. Div., Allied Chem. & Dye Corp., Box 970, Charlotte, N.C. (Jan. '56)

Breihan, Erwin R., Partner, Horner & Shifrin, 803 Shell Bldg., St. Louis 3, Mo. (Jan. '56) *MRP*

Brinegar, Ivan H.; *see* Bedford (Ind.)

Brophy, J. A., Secy-Treas., Public Service Com., Pleasant St., Bridgewater, N.S. (Jan. '56)

Brown, William W., Pacific Coast Repr., M. B. Skinner Co., 15240 De Pauw St., Pacific Palisades, Calif. (Jan. '56) *D*

Buchanan, George C., Purchasing Agent, Johnstown Water Co., 332 Locust St., Johnstown, Pa. (Jan. '56) *M*

Carlman, Leonard M., Supt. of Utilities, Hinsdale, Ill. (Jan. '56) *MD*

Carlson, Carl E., Sales Engr., Wallace & Tiernan Inc., 337 Pittock Block, Portland 5, Ore. (Jan. '56) *MP*

Carlson, Carl V.; *see* Fairfield (Calif.)

Cass, Glendale E.; *see* Robbinsdale (Minn.) Water Dept.

Chambers, A. B., Member, Board of Water Trustees, 1003 Locust St., Des Moines 7, Iowa (Jan. '56) *M*

Clapp, Hugh K., Engr., Water Bureau, Rm. 209, City Hall, Portland, Ore. (Jan. '56) *RD*

Clark, John Alexander, Engr., 829 S. Palmway, Lake Worth, Fla. (Jan. '56) *PD*

Clinebell, Paul W., Graduate Student, San. Eng., Univ. of Illinois, 201 Civ. Eng. Hall, Urbana, Ill. (Jr. M. Jan. '56) *RP*

Cobb, Leland J., Jr., Supt., Water Dept., City Hall, Tampa, Fla. (Jan. '56) *MRPD*

Cockburn, Donald H., Chief Engr., Herbert L. Coons & Assocs. Ltd., 194 Bloor St. W., Toronto 5, Ont. (Jan. '56)

Cocks, Theodore F., Contracting Engr., Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill. (Jan. '56) *M*

Cogbill, Jesse D., Chairman, Board of Comrs., Water Works Improvement Dist. No. 3, Box 86, Star City, Ark. (Jan. '56)

Comer, Robert J., Div. Engr., Div. of Water Eng., Dept. of Water, 600 Collins Park Ave., Toledo 5, Ohio (Jan. '56) *RPD*

Cox, Burton N., Jr., Project Engr., San. Dept., Rummel, Klepper & Kahl, 1021 N. Calvert St., Baltimore 2, Md. (Jan. '56) *D*

Crosier, Jack E., Asst. Supt. of Utilities, Cashmere, Wash. (Jan. '56) *MD*

Dalton, Thomas F., Chemist, Water Treatment Div., Magnus Chem. Co., Garwood, N.J. (Jan. '56) *RP*

Dawson, John R., Sr. Utility Accountant, Dept. of Water & Power, 207 S. Broadway, Los Angeles, Calif. (Jan. '56) *M*

Deaton, Tully, Chief Engr., Water Plant & Utilities, State Training School for Boys, Box 122, St. Charles, Ill. (Jan. '56)

de Jong, Tim, Chief Civ. Engr., Thomas B. Bourne Assoc. Inc., 832 Dupont Circle Bldg., Washington 6, D.C. (Jan. '56) *MPRD*

de Paula, Helio, Asst. to the Director, Dept. of Water & Sewerage, Prefeitura Munic. de B. Horizonte-Belo Horizonte, Minas Gerais, Brazil (Jan. '56)

Downingtown, Borough of, Robert H. McKinney Jr., Borough Mgr., 4 W. Lancaster Ave., Downingtown, Pa. (Corp. M. Jan. '56) *M*

Durward, David N., Gen. Mgr. & Secy.-Treas., Public Utilities Com., 62 Dickson St., Galt, Ont. (Jan. '56) *M*

Elling, Wilbur R., Comr., Massapequa Water Dist., 155 Fitzmaurice St., Massapequa Park, N.Y. (Jan. '56) *MD*

Endean, Frank H., Sales Engr., Rockwell Mfg. Co. of Canada, 90 Eglinton Ave. E., Toronto 12, Ont. (Jan. '56)

Evans, Donald R., Project Engr., Marshall, Macklin & Monaghan, 154 Merton St., Toronto 7, Ont. (Jan. '56)

Evans, Richard, Supt., Water Works, Kenton County Water Dist. No. 1, 31 E. 7th St., Covington, Ky. (Jan. '56) *PD*

Fairfield, City of, Carl V. Carlson, Director of Public Works, City Hall, Fairfield, Calif. (Munic. Sv. Sub. Jan. '56) *MD*

Fielding, Jack, Supt., Water & Light Plant, Hope, Ark. (Jan. '56)

Fitzgerald, Neil R., Operator, Softener Plant, Breckenridge, Mich. (Jan. '56) *P*

Fonley, John V., Asst. Supt., Water Dept., City Hall, Orange, Calif. (Jan. '56) *D*

Fulton, Ben B., Civ. Engr., Asst. to County Surveyor, Rte. 4, Billings, Mont. (Jan. '56) *MD*

Galper, Sam, Engr., Gore & Storrie Ltd., 1130 Bay St., Toronto 5, Ont. (Jan. '56)

Goodings, Robert A., Engr., Gore & Storrie Ltd., 1130 Bay St., Toronto 5, Ont. (Jan. '56)

Green, Billy Jack, Chemist, City of Abilene, Abilene, Tex. (Jan. '56) *M*

Green, Paul W., Mgr., Sales Office, American Cast Iron Pipe Co., 916 Walnut St., Bldg., Rm. 506, Kansas City, Mo. (Jan. '56) *R*

Hall, Howard C., Tech. Supervisor, St. Helens Div., Crown Zellerbach Corp., St. Helens, Ore. (Jan. '56) *P*

Hall, Lawrence, Supt., Water Works, Converse, Ind. (Jan. '56) *PD*

Halvorson, Otto A., Mech. Engr., Water Constr. Div. City Engr.'s, Rm. 401, City Hall, Milwaukee, Wis. (Jan. '56) *D*

Haney, J. B., Jr., Mgr., Water & Sewerage System, Canton, Ga. (Jan. '56) *MP*

Harrell, Frank F., Supt., Water Works, La Porte, Ind. (Jan. '56)

Harris, Lucian J., Dist. Sales Mgr., Chicago Bridge & Iron Co., 1700 Walnut St., Philadelphia, Pa. (Jan. '56) *M*

Hasegawa, George K., Civ. Engr., Horner & Shifrin, 803 Shell Bldg., St. Louis 3, Mo. (Jan. '56) *RP*

Hatton, Ray G., Sales Engr., Rockwell Mfg. Co. of Canada, 90 Eglinton Ave. E., Toronto 12, Ont. (Jan. '56)

Hewson, James F., Chief Engr., Water Div., Windsor Utilities Com., 787 Ouellette Ave., Windsor, Ont. (Jan. '56)

Hoffman, Hilbert L., Engr., in Charge, Water Resources Div., State Flood Control & Water Resources Com., 1330 W. Michigan St., Indianapolis, Ind. (Jan. '56) *R*

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M&H
ANNISTON ALA

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Hohman, Robert L., Civ. Eng. Asst., Dept. of Water & Power, Box 3669 Terminal Annex, Los Angeles 54, Calif. (Jan. '56) *MRD*

Honeycutt, Lex E., Director of Public Works, City Hall, Thomasville, N.C. (Jan. '56) *D*

Hursey, Otto R., Supt., Water Works, 3619 Central Ave., East Gary, Ind. (Jan. '56) *MRPD*

Izurieta Gomez, Ramon Verisimo, Chief of Fuentes, La Toma Filtration Plant, Guayaquil, Ecuador (Jan. '56) *MPD*

Jessup, Albert H., Cons. Engr., Quinton Engrs., Ltd., 812 W. 8th St., Los Angeles 17, Calif. (Jan. '56)

Jester, Ralph L., Trustee, Water Works, 209 Fleming Bldg., Des Moines, Iowa (Jan. '56) *M*

Jones, Frank C., Chief Engr., Arizona Fire Rating Bureau, 215 Lehrs Tower, Phoenix, Ariz. (Jan. '56) *D*

Kaun, H.: *see* Stuttgart (Germany) Technische Werke

Kennedy, David V., San. Engr., State Dept. of Fish & Game, 926 J. St., Sacramento, Calif. (Jan. '56) *MD*

Khalifa, H. S., Graduate Student, Univ. of Illinois, 1105 W. Clark St., Urbana, Ill. (Jr. M. Jan. '56) *P*

Kirkpatrick, Wallace A., Chemist, Northern States Power Co., Testing Lab., 1600 Chestnut Ave. N., Minneapolis, Minn. (Jan. '56) *P*

Kissell, James D., Engr., Fulton & Cramer, 922 Trust Bldg., Lincoln, Neb. (Jan. '56) *PD*

Lane, Victor C., Dist. Sales Mgr., Pennsylvania Salt Mfg. Co., 2328 Buhl Bldg., Detroit 26, Mich. (Jan. '56)

Larsen, William C., Owner, William C. Larsen P.E., 143 Shelbourne Rd., Rochester 20, N.Y. (Jan. '56) *MRPD*

Larson, Winston C., Cons Engr., Winston C. Larson & Assocs, 720 Lake Ave., Detroit Lakes, Minn. (Jan. '56) *MP*

Leaverton, Robert L., Prin. Asst. Supt., Constr. & Maint., Bureau of Water Supply, 2331 N. Fulton Ave., Baltimore, Md. (Jan. '56) *M*

Le Blanc, Paul J., Jr., Secy.-Treas., Red Oak Water Co., Inc., Box 2064, Baton Rouge, La. (Jan. '56) *MD*

Livesay, E. Boyd, Supt., Brunswick-Topsham Water Dist., 9 Town Hall Pl., Brunswick, Me. (Jan. '56 *MRP*

Long, Malcolm C., Water Supervisor, Public Service Dept., 164 W. Magnolia Blvd., Burbank, Calif. (Jan. '56) *MRD*

Lukas, Vincent de P., San. Engr., General Elec. Co., 202 State St., Schenectady, N.Y. (Jan. '56) *RP*

Macklin, Harold L., Partner, Marshall, Macklin & Monaghan, 154 Merton St., Toronto, Ont. (Jan. '56)

Marqueling, H. E., Acting Chief Engr., Oregon Insurance Rating Bureau, Box 70, Portland 7, Ore. (Jan. '56) *D*

Martin, R. F., Supt., Water Treatment Plant, Cramerton Div., Burlington Industries Inc., Box 477, Cramerton, N.C. (Jan. '56) *P*

McKinney, Robert H., Jr., *see* Dowingtown (Pa.)

McNeice, L. G., Civ. & San. Engr., McNeice Assocs., 28 Coldwater Rd. W., Orillia, Ont. (Jan. '56)

Metcalf, E. M., Business Mgr., Water Dept., City Hall, Tampa, Fla. (Jan. '56) *M*

Miller, Donald T., Pres., Turbine Equipment Co., 63 Vesey St., New York, N.Y. (Jan. '56) *D*

Mitchell, Robert L., Jr., Asst. to Secy., Chlorine Inst. Inc., 50 E. 41st St., New York 17, N.Y. (Jan. '56) *P*

Moore, K. W., Project Engr., Gore & Storrie Ltd., 1130 Bay St., Toronto 5, Ont. (Jan. '56)

Mouquin, William H., Dist. Mgr., De Laval Steam Turbine Co., 1225 Harlem Ave., Forest Park, Ill. (Jan. '56) *MD*

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Mouser, M. E., Designer, Consoer, Townsend & Assocs., 351 E. Ohio St., Chicago, Ill. (Jan. '56) *MPD*

Nienow, Wallace G., City Engr., City Hall, South Milwaukee, Wis. (Jan. '56) *MRPD*

Orth, Robert F., Mgr., Transite Pipe Dept., Johns-Manville Sales Corp., 22 E. 40th St., New York 16, N.Y. (Jan. '56)

Owen, Curtis E., Asst. Gen. Mgr., Johnstown Water Co., 332 Locust St., Johnstown, Pa. (Jan. '56) *M*

Owen, Paul E., Asst. Utilities Mgr., Box 446, Oxnard, Calif. (Jan. '56) *MD*

Oxford, W. F., Jr., Section Head, Corrosion & Analytical Dept., Sun Oil Co., 1096 Calder Ave., Beaumont, Tex. (Jan. '56) *P*

Pearce, John C., Pres. & Gen. Mgr., Red Oak Water Co., Inc., Box 2064, Baton Rouge, La. (Jan. '56) *MD*

Phelan, Edward J.; *see* Vandalia (Ohio) Board of Trustees of Public Affairs

Phillips, Albert W., City Engr., 4305 Santa Fe Ave., Vernon 58, Calif. (Jan. '56 *RD*

Quiroba, Helena (Miss), Civ. Engr., Inst. Nacional de Obras Sanitarias, Caracas, Venezuela (Jan. '56)

Rapids City, Village of, Joseph Van Hautte, Village Clerk, Box 18, Rapids City, Ill. (Munic. Sv. Sub. Jan. '56) *M*

Ray, John B., Mgr., Memorial Bend Utility Co., 12947 Memorial Dr., Houston, Tex. (Jan. '56) *M*

Reardon, Robert R., Supt., Water Works, Scottsburg, Ind. (Jan. '56)

Regard, Edward J., Sales, Gen. Chem. Div., 3357 W. 47th Pl., Chicago 32, Ill. (Jan. '56) *P*

Robbinsdale Water Dept., Glendale E. Cass, Supt., City Hall, 4145 Hubbard, Robbinsdale, Minn. (Munic. Sv. Sub. Jan. '56) *MP*

Robinson, John T., Cons. Engr., 620 Larkspur Ave., Corona Del Mar, Calif. (Jan. '56) *MRPD*

Rutz, Aldelmo, San. Civ. Engr., Thomas B. Bourne & Assocs. Inc., APO 239, c/o Postmaster, San Francisco, Calif. (Jan. '56) *MRP*

Ryerson, Peter G., Distr. Supt., Dept. of Public Works, Bureau of Water, 60 Collard St., Jersey City, N.J. (Jan. '56) *D*

Scarce, LeRoy E., Water Bacteriologist, South Dist. Filtration Plant, 3300 E. Cheltenham Pl., Chicago 49, Ill. (Jan. '56) *P*

Schliekelman, R. J., Public Health Engr., State Dept. of Health, Des Moines, Iowa (Jan. '56) *R*

Sellner, Edward P., San Engr., Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Jan. '56) *R*

Sessums, Francis B., Chief, Water Resources Div., State Dept. of Public Works, Box 4155, Capitol Sta., Baton Rouge, La. (Jan. '56) *R*

Shaw, Luther, Supt., Munic. Water System, McNeil, Ark. (Jan. '56) *M*

Shearer, Samuel D., Jr., Graduate Research Asst., School of Public Health, San. Eng. Dept., Univ. of North Carolina, Chapel Hill, N.C. (Jr. M. Jan. '56) *P*

Siler, George T., Owner, Clemenceau Water Co., Clemenceau, Ariz. (Jan. '56) *M*

Skeans, Horace G., Supt. of Production, Water Plant, McAllen, Tex. (Jan. '56) *MP*

Stuttgart, Technische Werke der Stadt, H. Kaun, Generaldirector, Lautenschlagerstrasse 21, Stutt-

Vandalia Board of Trustees of Public Affairs, Edward J. Phelan, Pres., Box 385, Vandalia, Ohio (Munic. Sv. Sub. Jan. '56) *M*

Van Hautte, Joseph; *see* Rapids City (Ill.)

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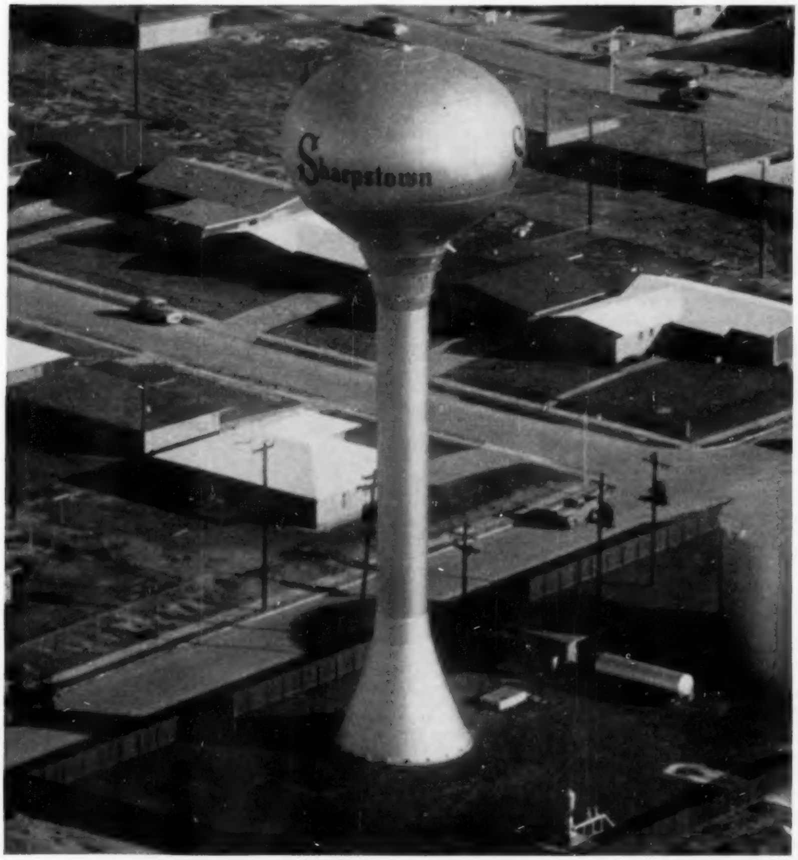
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Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Infilco Inc.
Wallace & Tiernan Inc.
Reservoirs, Steel:
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Sand Expansion Gages; see Gages
Sleeves; see Clamps
Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Sludge Blanket Equipment:
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.
Sodium Hexametaphosphate:
Calgon, Inc.
Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.
Sodium Silicate:
Philadelphia Quartz Co.
Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.

Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Softening Chemicals and Compounds:
Calgon, Inc.
Cochrane Corp.
General Filter Co.
Infilco Inc.
Morton Salt Co.
Permutit Co.
Tennessee Corp.
Standpipes, Steel:
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.
Storage Tanks; see Tanks
Strainers, Suction:
James B. Clow & Sons
M. Greenberg's Sons
Johnson, Edward E., Inc.
R. D. Wood Co.
Surface Wash Equipment:
Cochrane Corp.
Permutit Co.
Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries)
Fischer & Porter Co.
Omega Machine Co. (Div., B-I-F Industries)
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.
Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Water Conditioning Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.
Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.
Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries)
Cochrane Corp.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.
Tenoning Tools:
Spring Load Mfg. Corp.
Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.
Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.
Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.
Valves, Altitude:
Golden-Anderson Valve Specialty Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.
Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Shower Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
S. Morgan Smith Co.
R. D. Wood Co.
Valves, Detector Check:
Hersey Mfg. Co.
Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
Ross Valve Mfg. Co., Inc.
Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
DeZurik Shower Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
M & H Valve & Fittings Co.
Mueller Co.
Philadelphia Gear Works, Inc.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.
Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.
Valves, Regulating:
DeZurik Shower Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.
Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries)
Infilco Inc.
Simplex Valve & Meter Co.
Waterproofing:
Inertol Co., Inc.
Water Softening Plants; see Softeners
Water Supply Contractors:
Layne & Bowler, Inc.
Water Testing Apparatus:
Wallace & Tiernan Inc.
Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.
Well Drilling Contractors:
Layne & Bowler, Inc.
Well Screens:
Johnson, Edward E., Inc.
Wrenches, Ratchet:
Dresser Mfg. Div.
Zeolite; see Ion Exchange Materials

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